THE DISEASES AND PESTS
OF THE RUBBER TREE

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PLATE I.

FOMES LIGNOSUS

Upper surface Specimen half dry

THE DISEASES AND PESTS OF THE RUBBER TREE

BY

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PREFACE

In 1911 the diseases which were known to attack the rubber tree were described in *The Physiology and Diseases of Hevea brasiliensis.* The number of recorded diseases was then comparatively small, and it was possible to include with them a general account of the structure and physiology of the tree, and a summary of those tapping experiments which promised to afford a foundation for a theory of rubber tapping. That book has now been out of print for some time, and several inquirers have suggested the issue of a second edition. But the number of known diseases of *Hevea* has, unfortunately, been considerably extended during the last eight years, while the work of numerous investigators in this field has added largely to our knowledge of both old and new ones. Consequently, rubber diseases now demand a volume to themselves; and it has therefore been decided to divide the subject-matter of the former book, and to publish a separate account, revised and brought up to date, of the diseases and pests only. It is hoped that it will be possible, at some future date, to deal similarly with the other half of the original volume.

As the book is intended primarily for the rubber planter, technical botanical details have been avoided as much as possible. It is not practicable to exclude them altogether, nor, indeed, is that necessary, for rubber cultivation has made the planter familiar with technical botanical terms to a degree hitherto unknown in tropical agriculture. Microscopic details of the fungi have in general been omitted, the scientific descriptions of them, which are of value only to a

mycologist, being included in a separate chapter for the convenience of those who may desire to refer to them.

The illustrations have been chosen with the idea of enabling the planter to identify the different diseases. They represent typical stages of the various fungi or diseases, but, as fungi are usually highly variable, one cannot figure all stages without making the cost of the book prohibitive.

A brief summary of the diseases described, with references to the illustrations, has been added to each of the principal chapters. These, it is hoped, will prove of service in a rapid survey for purposes of identification.

A chapter on the principal pests of *Hevea* has been included. Up to the present, insect pests of *Hevea*, with the exception of the notorious *Termes gestroi*, have proved of minor importance in comparison with fungus diseases.

The aim of a book of this kind is not only to provide the planter with a means of identifying and dealing with known diseases, but also to enable him to decide whether any observed abnormal appearance or disease is unrecorded and consequently ought to be brought to the notice of a mycologist. Rubber cultivation demands constant vigilance in this respect, since, because of the greater value of the individual plant and the unique method of obtaining the crop, an outbreak of disease may have a more serious result than in the case of such products as tea, sugar, etc. That the future of plantation rubber is largely dependent upon the effective combating of disease has been repeatedly emphasised; and it is the duty of rubber planters, and those responsible for the management of rubber estates, to resist any attempt to minimise the importance of that aspect of rubber cultivation and research.

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GENERAL SANITATION

In olden times diseases of plants were regarded as "visitations" and allowed to rage unchecked. In seasons favourable to their development their ravages caused widespread damage, and, in some instances, the almost total ruin of a country; and only the advent of less favourable years brought relief. Even after it had been proved that plant diseases were due to the action of specific organisms, and that some steps could be taken to combat them, little improvement resulted at first, because, in the majority of cases, nothing was attempted until the disease had obtained so strong a footing that nothing could be done successfully at any reasonable cost. The fungus of coffee leaf disease (*Hemileia vastatrix*) was recognised to be a very destructive pest in 1869, but it was not until ten years later that active measures were taken against it. There is little doubt that much of this delay was due to a reluctance to admit that any disease existed, and it is only within the present century that public opinion in planting countries has come to understand that plant diseases are as inevitable as those of men and animals.

This acknowledgement of the inevitability of disease leads immediately to a recognition of the fact that it is necessary to be always on the alert to observe any abnormal or suspicious appearances, and to have inquiry made into them at the earliest possible moment. Speed is an essential factor in the treatment of diseases, and to deal with any one of them successfully it must be attacked in an early stage. In *Hevea*, at least, this proposition is thoroughly understood; and there is little fear that any disease will be allowed to proceed unchecked or unobserved in Eastern plantations

so long as the present vigilance of estate superintendents is maintained.

But though the recent advance of public opinion in this respect has been extraordinarily rapid, it still falls short of what is absolutely necessary. The continued study of plant diseases has shown what conditions are favourable to their development, and consequently what precautions should be observed if they are to be avoided or minimised as far as is humanly possible. In short, such knowledge enables us to advance from the idea of remedial measures to that of preventive measures. It is no longer permissible to adopt systems of planting or methods of cultivation without considering their probable effect when diseases arise, and in the light of our present knowledge that effect can in many cases be predicted with a close approximation to certainty. The pathologist should be consulted beforehand, not five or six years afterwards when some disease has already appeared; and in the absence of any such consultation he would fail in his duty if he did not point out how new or old planting practices tended to promote disease.

Furthermore, in addition to preventive measures which must date from the opening up of the estate, there are many details of general sanitation which should be attended to if it is desired to keep the trees in a healthy condition. Some of these are indicated in the present chapter.

Jungle Stumps

By the usual method of clearing jungle land for planting in the tropics all the stumps of the trees are left *in situ*. That is a fact which agricultural experts and inventors in temperate climates find some difficulty in realising. In temperate countries the trees are felled, and the stumps are afterwards extracted because the land is to be worked by machinery; but in the tropics machinery is not employed, and therefore this necessity does not exist. Further, tropical trees, especially on low-lying land or in "rain forest," are often furnished with high buttress roots, and to economise labour they are cut above the latter. Thus, not only are stumps left to decay by natural means, but they are larger and more numerous than in temperate countries.

The decay of these stumps is brought about by the agency of fungi, the spores of which alight upon the exposed wood and germinate there. The fungus threads (hyphae) attack the wood, and either gradually consume it or else absorb certain parts of it so that the remainder falls into powder. In either case the fungus feeds unseen upon the tissues of the stump, and in due course constructs fructifications of varied form and colour on the exterior of it. The majority of these fungi are merely saprophytic, *i.e.* they can live only on dead tissues, but some of them can act as parasites on occasion, and it is the latter which cause trouble. All the root diseases of *Hevea*, Tea, and Cacao which have been investigated with any approach to completeness have been found to originate, in the most general case, on a neighbouring stump; in some cases it is the stump of a jungle tree, while in others it is the stump of a tree which has been planted for shade and then cut down. The known root diseases of the plants mentioned rarely attack the plant directly, *i.e.* by the germination of spores upon the plant; they all require, as a rule, an external base of operations, and this they find in the dead wood of an adjacent stump, or, in some cases, in felled timber.

The general plan of attack is as follows: The spores of the fungus are blown on to the exposed wood of the stump, and if the weather conditions are favourable they germinate and their hyphae grow down into it. These hyphae continue growing in the dead tissues until they have permeated both the stem and the roots, and then they spread from the roots of the stump to the roots of adjacent living trees. Some fungi can only spread to other plants if the roots of the latter are in contact with those of the host stump; others, however, can spread freely through the soil, drawing food from the supply in the stump which served as a base. Each stump thus affords a centre of disease, spreading destruction in an ever-widening circle.

In addition to spreading the disease by means of radiating fungus hyphae in the soil, each infected stump produces fructifications of the fungus, and these liberate spores which convey infection to other stumps. In some cases fructifications are produced at intervals from shortly after the stump is first attacked until the time when it is completely decayed;

while in the case of other fungi the stump only bears fructifications when it is in the last stages of decay.

If there were no dead stumps or fallen timber on Rubber plantations there would be very little root disease. But it is not an easy matter to get rid of these, and whatever method is adopted the cost is high. Still, the fact that root diseases depend on the presence of decaying wood of some kind is generally realised, and it may be said that it is now the exception rather than the rule, at least in Ceylon, to find a Rubber estate which has not cleared up all dead stumps and felled logs. It is important to note that this work has been undertaken, not from a desire to make the estate look clean, but because it has been definitely established beyond any possible doubt that decaying stumps promote root diseases. Of course, under existing conditions, the majority of estates have got rid of their stumps only after disease has made its appearance. It would, however, be foolish if younger estates did not profit by their experience and begin to remove jungle stumps as soon as possible after opening.

Owing to the long period which must elapse before any return can be obtained, an estate must be planted up as soon as possible after felling and burning off. Hence, apart from other reasons, such as loss of soil, etc., it is perhaps too much to expect that the land will be cleared of stumps before the Rubber is planted. Stump-extraction will generally follow planting in ordinary estate routine. But here we are met with an insurmountable difficulty. Any stump-extracting apparatus capable of dealing with jungle stumps cannot be employed after the estate has been planted up without causing an enormous amount of damage; and those which can be used with comparative safety are of very little value. As a rule, inventors of stump-extracting machinery underestimate the difficulty of the problem with which they have to deal, owing to absence of any first-hand acquaintance with local conditions. At the present time nothing more can be recommended than digging out the stumps to a depth of two or three feet by manual labour; and that operation should be begun as soon as the plants are established.

Lateral roots should be extracted as far as possible. In the case of a very large stump, with spreading buttress roots,

where the expense of removal is considered prohibitive, a trench should be dug round it, cutting through all the lateral roots. The laterals should be taken out immediately, and the stump itself left until it has decayed to some extent, when it can be removed more easily. The trench should be kept open all the time the stump is left.

After the stumps have been dug out they must be burnt. It is unnecessary to point out that this can be done with less risk of damage the younger the Rubber.

Thinning out

Close planting, with the intention of thinning out in later years, was never widely adopted; in the majority of cases estates were planted up at the distances it was considered the trees would remain permanently. It needed, however, only the efflux of time to demonstrate the truth of the prophecies of mycologists who contended that *Hevea* could not possibly exist in a healthy condition when planted two hundred to the acre; and the necessity for thinning out all the earlier-planted Rubber is universally admitted.

The arguments for and against close planting are now ancient history, and a detailed recapitulation of them would be merely flogging a dead horse. The points definitely agreed upon are:

(1) Close planting leads to poor bark renewal, because the crown of the tree is not large enough to manufacture a sufficient quantity of food.

(2) The yield falls off, in closely-planted areas, as the trees grow older. The age at which this effect begins to be evident depends on the rate of growth of the trees; it has been observed, in the case of trees planted 15 feet apart, at the age of twelve years, in a district at an elevation of 1500 feet, where the growth was comparatively slow, but it has been recorded to occur after the sixth year in the case of Rubber planted 14 feet apart in Malaya.

(3) Disease is more prevalent in closely-planted areas.

Some of the older Rubber was planted 10 feet by 10 feet, or, in a few instances, 8 feet by 8 feet. In such cases it was permissible to begin thinning out by cutting out alternate rows, as an ample number of trees was left for further thinning

by selection. But in the case of Rubber planted at wider distances originally, thinning should be done by selection throughout, the diseased and weakly trees and the poor yielders being removed first.

Closely-planted trees "run up." Their lower branches are killed by the dense shade, and their crowns often consist of a few branches directed more or less vertically upwards and bearing comparatively few leaves. The application of manure only increases this effect. The ultimate condition of such trees after thinning is still in doubt. It does not appear probable that they will be able to develop lateral branches lower down, and improvement will, in general, be limited to the existing crown. This, however, refers more particularly to trees planted at 12 feet apart or less. Thinning out at the present time is being carried on over any area which bears more than one hundred trees to the acre, and in the majority of cases the trees have not yet assumed the shape described.

Surprise has been expressed that the lower branches of Rubber trees continue to die after a field has been thinned. Apart from any question of disease, this is to be expected to some extent, as, after thinning, the branches which were developed under partial shade are exposed to full sunlight, and this may have an injurious effect, at least for a limited period. Another effect observable after thinning is that the semi-vertical branches are often too weak to maintain their position, and bend over, sometimes ultimately breaking. Such branches should be cut back before they break.

The idea of extracting as much rubber as possible from a tree before taking it out has been generally abandoned. Whenever it is destroyed it will contain some rubber, and when many trees have to be removed, it is better to cut one's losses at the beginning rather than to run the risk of introducing disease by tapping them until they are in a moribund condition. The trees must be uprooted, and all the woody parts removed and burnt. Felling by elephants is a favourite method in Ceylon, and it appears to be, on the whole, the most efficient. In this method the surface roots of the tree are usually cut through first, and in some cases the larger branches are lopped in order that the surrounding trees may not be injured by its fall.

The tap root must be extracted to a depth of at least two feet. When thinning was first taken in hand, many trees were cut off at ground level, and their stumps have proved just as dangerous as jungle stumps. The root diseases caused by *Fomes lignosus*, *Ustulina*, *Poria hypobrunnea*, and Brown Root disease, have all been found to develop from the stumps of felled *Hevea*. Where the lateral roots have been severed these should be pulled up as far as they will come and then cut off; laterals, two or three inches in diameter, left with their cut ends sticking up above the soil, have developed *Ustulina* and *Poria hypobrunnea*.

When thinning out was first begun it was anticipated that the development of *Botryodiplodia Theobromae* on the *Hevea* logs would lead to extensive outbreaks of Die-back. That has not been realised. On the other hand, *Ustulina zonata* and *Poria hypobrunnea* are among the commonest fungi which occur on rotting *Hevea* logs, while *Fomes lamaoensis*, the fructification of Brown Root disease, has been found on them on several occasions. It is evident, therefore, that felled *Hevea* must be removed; if anything, it is more dangerous than jungle timber.

Hevea is now being thinned out to about eighty or one hundred trees to the acre, with acknowledgement that the number must ultimately be still further reduced. What the final number will be cannot yet be decided, but, according to the opinion current at the present time, based on the experience of the last six years, it will not exceed sixty. This again brings forward the question what is the most preferable method of planting *Hevea* in the first instance, and on this point there are two opposed policies.

The view most generally held is that the trees should be planted at the distances it is intended they should finally stand. If planted 25 feet by 25 feet, or 30 feet by 20 feet, there will in either case be about seventy trees to the acre, and this would allow for a loss, by disease or otherwise, of ten trees before the number fell below what is at present considered the probable maximum. The objections raised against this plan are—(1) that the loss of soil through wash will be much greater than if the trees were planted closer, and (2) the return in the earlier stages of tapping will be very small. To the first of these it is replied that the wash may

be prevented by the use of a suitable cover plant, while the relevance of the second has been considerably diminished by the change which has taken place in the general view with regard to the size at which *Hevea* should be brought into tapping.

The alternative suggestion is that the trees should originally be planted closer, say 20 feet by 15 feet, as in previous planting, and thinned out to half the number, or approximately 20 feet by 30 feet, before the trees begin to interfere with one another. In support of this plan, it is urged that there will be less wash, that there is a greater number of trees to select from in thinning out, and that the return would be greater when tapping was first begun. The last of these contentions is the one which usually carries most weight with the planter, though it is questionable whether, under present conditions, it is really as attractive as it seems. Trees are not now brought into tapping as early as they were; it is realised that, if an estate can afford it, it is better to wait until the trees are 24 inches in girth at 3 feet than to begin to tap them when they are 18 inches, as was previously the case. Again, the trees which are to be thinned out must be removed before the crowns begin to interfere with one another, and, at 15 feet apart, they will certainly interfere before they attain the required girth of 24 inches. The trees should be so far apart at the beginning that they can spread out their crowns without interference and build up a normal framework of branches, not because of any aesthetic ideals, but because the manufacture of plant food is carried on by the leaves, and a tree which is subjected to the treatment which *Hevea* undergoes must be in a position to manufacture food in sufficient quantity to ensure a satisfactory bark renewal.

Apart from the above, it is almost inconceivable that any one should now deliberately adopt a planting method which involves extensive thinning out. The thinning which has been done, it must be emphasised, was never contemplated; the trees were planted at the distances it was considered they would stand permanently, and they have been removed because experience has proved that *Hevea* cannot be grown so close. The full results of thinning out have yet to be realised, but when one considers the cost of the

operations, the dangers of root disease, the loss of trees through scorching, and the general insanitary condition of the estate owing to the previous close planting, it is indeed difficult to imagine that any one would wish to repeat the experience.

It is still held in some quarters that *Hevea* may be planted closer on hill-sides than on the flat, presumably because the slope raises the crown of each tree above that of the tree immediately below it, and thus diminishes the amount of interference between them. But the fact is overlooked that the slope automatically brings the trees nearer together. To take an extreme case, if the slope of the hill is 60°, and the trees are planted 20 feet apart along the slope, they are only 10 feet apart horizontally; if the slope is 30°, they are $17\frac{1}{2}$ feet apart horizontally. If anything, therefore, the trees should be further apart on sloping ground, provided the growth is normal. One has only to examine a field on a steep hill-side thinned out to less than a hundred trees to the acre to realise this.

Intercrops, Cover Plants, etc.

In the early days of Rubber planting much discussion centred on the subject of intercrops, *i.e.* products which could be grown permanently between the lines of *Hevea*, or which might be grown for the first few years only, so that some revenue might be obtained before the Rubber came into bearing. Practical applications of the schemes then advised have not been numerous; as a rule, Rubber estates have grown rubber only, though in Ceylon Cacao was interplanted in a few cases, and in Malaya and Java Cassava or Coffee.

In Ceylon interplanting has usually meant the planting of *Hevea* through existing Tea or Cacao. This is not strictly interplanting, but a gradual replacement of the previous product by Rubber, and the method was dictated by necessity, not by choice. Perhaps it was at first expected that the two products would flourish side by side, but experience has proved that, as a rule, when the Rubber has grown up, one of them must be removed.

In general, it may be said that the rubber planter has

concluded that intercrops are not worth the trouble from the financial point of view. They have also been recommended on the ground that they will hinder the spread of disease; but, as advised or practised hitherto, intercrops have tended rather to promote the spread of disease than otherwise.

From a purely mycological standpoint there are two points to be considered when selecting an intercrop or a cover plant for Rubber, viz. its effect on the general hygienic conditions of the estate, and the diseases to which it is liable. It is admittedly wrong to select a plant which is subject to the same diseases as *Hevea*, and it is also inadvisable to choose one which will grow so tall and dense that the bottom shade and consequent humidity are thereby unduly increased. An intercrop which would grow no higher than Tea is usually allowed to grow would be ideal, while a cover plant should, if possible, be lower still.

Cacao has proved quite unsuitable as an intercrop for *Hevea*. When established, the shade and humidity in the mixed plantation are greater than if *Hevea* had been planted throughout instead of Cacao, and consequently the general sanitary condition of the whole estate is lowered. In addition to that, the diseases of the two plants are in many cases identical. Brown Root disease and *Fomes lignosus* attack both *Hevea* and Cacao; *Botryodiplodia Theobromae* causes Die-back both in *Hevea* and Cacao, and is abundant on decaying Cacao pods; and *Phytophthora Faberi*, which is the cause of Cacao pod disease and canker, similarly produces pod disease and canker in *Hevea*. But the chief trouble from Cacao arises when the Cacao is cut out. If it is simply cut off at ground level, as has been done in many cases, the stumps frequently develop *Ustulina*, *Fomes lignosus*, or *Fomes lamaoensis*, which spread to and cause root disease in the surrounding Rubber trees. Of these, *Fomes lamaoensis* (Brown Root disease) is the most common, and several instances have occurred in which large areas under *Hevea* were permeated with Brown Root disease, owing to the development of this fungus on Cacao stumps. When Cacao is removed from a mixed *Hevea* and Cacao estate, it must be uprooted. Taking all things into consideration, it must be concluded that, from a mycological point of view, Cacao

is the worst possible intercrop which could be chosen to plant among *Hevea*.

Coffee has been interplanted on several estates in Malaya and Java, and a few in Ceylon. The diseases which Coffee shares with *Hevea* are *Fomes lignosus*, Brown Root disease (*Fomes lamaoensis*), Pink disease, and Thread Blight. Pink disease is likely to be prevalent if the coffee is thickly planted.

Tea was never interplanted at the same time as the *Hevea*, but the latter was planted through old Tea in Ceylon over large areas. In course of time the Tea ceased to be remunerative, owing to the shade and root competition of the *Hevea*, and was either taken out or allowed to die out. In the latter case, or when the Tea was simply cut off at ground level, extensive developments of root disease have followed. In 1910 it was known that the *Hevea* might be attacked by *Ustulina zonata*, which is the cause of the commonest root disease of Tea in Ceylon, but since then it has been found that the root disease of *Hevea* which most usually spreads from decaying Tea stumps is that caused by *Fomes lignosus*, and the worst outbreaks of the latter disease in Ceylon have occurred on old Tea fields where the tea was cut down at ground level.

As the converse of the above, it may be recorded that on estates at medium elevations in Ceylon, where it has been decided to keep the Tea and cut out the Rubber from mixed fields, leaving the Rubber stumps has resulted in the death of large numbers of the surrounding Tea bushes through the root disease caused by *Botryodiplodia Theobromae*, which has spread to the Tea from the decaying Rubber stumps.

Kapok stumps (*Eriodendron anfractuosum*) among *Hevea* have been found to give rise to Brown Root disease.

Where cover plants or green manure plants have been adopted *Crotalaria striata* has been largely employed. This is generally sown thickly, and in most cases it does not grow higher than 3 feet. It suffers from two leaf diseases, but neither of these is likely to attack *Hevea*. One of these, which takes the form of circular, dry, brown spots, often concentrically zoned, is caused by *Sphaerella Crotalariae*. The other is caused by *Parodiella perisporioides*, a well-known parasite of leguminous plants in the tropics; the fungus forms minute black points, scattered over the upper surface

of the leaf, but the leaf is not killed—it simply curls up. This latter disease is most prevalent on old *Crotalaria*, after it has been cut back, and on self-sown plants. There is, however, a danger in *Crotalaria* in some districts, where it grows much taller and stouter than it does in Ceylon, *e.g.* in some parts of Southern India. In these localities it may grow to a height of 9 feet in a year, without flowering, and may acquire a woody stem about an inch in diameter: such plants are attacked by Pink disease (*Corticium salmonicolor*), and the disease soon spreads to the *Hevea*. There is no danger in growing *Crotalaria* among *Hevea* in most countries; and where the growth is so vigorous that it forms a tall jungle, some smaller green manure and cover plant must be adopted, or the *Crotalaria* must be cut down earlier. Another species of *Crotalaria* (*Crotalaria fulva*) has been found to be subject to the attack of *Poria hypobrunnea.*

Tephrosia candida has been largely planted as a green manure crop during recent years. When it is old, and the stem has become thick and woody, it is sometimes attacked by the root disease caused by *Poria hypobrunnea.* It would appear that this does not occur, in the low country of Ceylon, until the plant is over two years old, and has been repeatedly lopped. Consequently a time limit of about two years should be set to the growth of *Tephrosia candida*, and at the expiration of that time the old stumps should be uprooted and burnt.

Any green manure plant which grows tall should not be planted in dense masses; the lower the plant the less is the danger of disease. A plant which did not exceed a foot in height would be ideal, and could be sown as thickly as desired.

There is often a tendency to let green manure plants run too long. In temperate climates, such a crop is often ploughed in at the end of a month; but in the tropics the idea usually appears to be to make it run as long as possible, and to obtain some profit by selling seed. There is little advantage in a green manure plant as such until it is cut down and mulched in.

Albizzia moluccana, planted through *Hevea* for green manuring, and subsequently felled, has been found to give rise to the root disease caused by *Ustulina zonata.* The

fungus develops on the *Albizzia* stumps and travels along the lateral roots to any *Hevea* roots which happen to be in contact with them. *Albizzia* stumps must be dug out.

The thorny dadap, or Bois Immortelle (*Erythrina umbrosa*), after being felled has been known to develop *Fomes lignosus* in abundance on its stumps and fallen logs. In the worst case the trees were about thirty years old, and had originally been planted as shade for Cacao. *Hevea* was subsequently planted through the Cacao, and some years later the *Erythrina* was ringed. The development of *Fomes lignosus* became apparent at the time the ringed trunks fell over. *Fomes lignosus* has also been found to occur on the smooth dadap (*Erythrina lithosperma*), and to kill out old trees.

The root diseases of *Hevea*, which are known to spread to the rubber tree from the stumps of cultivated plants, may be enumerated as follows :

Brown Root disease, from stumps of *Hevea*, Cacao, Ceara Rubber, Kapok, Grevillea.

Ustulina zonata, from stumps of *Hevea*, Tea, Cacao, *Albizzia*.

Fomes lignosus, from stumps of *Hevea*, Tea, Cacao, Jak, Bois Immortelle, and Dadap.

Poria hypobrunnea, from stumps of *Hevea* and *Tephrosia candida*.

It is evident that when an intercrop has ceased to be remunerative and it is desired to remove it, or when a green manure plant is to be dispensed with, it should be removed completely, not allowed to die out and decay *in situ*. Moreover it is not sufficient merely to cut the plant down ; the stumps must be extracted as well. All the available evidence points to the conclusion that no stumps of any kind can be left among *Hevea* without incurring the risk of serious losses through root disease.

Pruning

On many estates lateral branches which arose from the lowest six feet or so of the stem have been pruned off ; or when trees forked near ground level one stem has been removed. In the majority of cases the branch or stem has been sawn across a few inches from the main stem, thus

leaving a "stub" two or three inches long. This was the method recommended years ago, before the principles of plant physiology were applied to garden practice.

It is now generally recognised that the bark will never grow over such a stub, and that the end always remains exposed and affords a point of entry for destructive fungi. In *Hevea* the stub generally dies back. The current of water and food passes up and down the main stem, and the stub is side-tracked. When the stub is dead the bark and wood of the stem grow round it and encircle it with a collar of new tissue; and when the stub decays and falls out, a cup is left, in which rain-water collects, with the result that a rot extends into the wood of the main stem.

Branches should be pruned off in such a way that the wound will be healed rapidly by the growth of new bark over it, and the modern pruner obtains the desired effect by cutting off the branch as close to the main stem as possible. The cut should be made parallel to the main stem and close to it; it should not be made perpendicular to the branch which is cut off. According to the old idea the cut should be made so as not to injure the bulge at the base of the branch; the modern pruner cuts right through the bulge, and endeavours to leave the stem as smooth as possible, *i.e.* without any projecting remains of the branch. He certainly makes a bigger wound, but as the bark has only to grow on in a straight line, it heals over completely in a comparatively short time.

Pruning off large branches should never be done by a single operation. If they are sawn off close to the stem the branch falls when partly cut through, and usually tears off part of the stem. The first cut should be made about a foot away from the stem, on the under side of the branch, and continued about half-way through it. A second cut should then be made two or three inches farther away from the stem, on the upper surface, and this should be continued until the branch is severed. Finally the stub should be sawn off flush with the stem.

It is necessary to have a gang of coolies on a Rubber estate trained to remove dead branches and to prune where it is considered necessary; they should be taught the difference between pruning trees and chopping firewood, and should be provided with proper tools. At least once a year a complete

round of the estate should be made, and all dead and broken branches pruned off.

The Protection of Wounds

Wounds made by pruning off large branches, or by lopping trees to get rid of Pink disease, or by excising extensive areas of cortex attacked by canker, must be protected in some way or other to prevent the entrance of fungi into the tree through the exposed wood. If the wounds are large, so that new bark cannot be expected to grow over it for some years, the wood, if left unprotected, will gradually decay, and large cavities may be formed.

Coal tar is the best substance to employ for covering wounds. Stockholm tar has been found to cause more damage than coal tar in all the recorded experiments, and from a mycological point of view it is too evanescent. The tar should be applied cold, so that it does not run unduly over the surrounding bark, but, in the case of *Hevea*, no appreciable damage is caused if the tar happens to be applied to the bark round a wound. Where it is found that coal tar does not stop the entrance of borers, the wood should first be painted with Solignum, or Brunolinum, and tarred when that is dry.

White lead paint is extensively used in orchard practice for protecting pruning cuts.

Experiments have shown that the cowdung and clay mixture which has been so long in use in the tropics is not as effective in promoting the rapid healing of a wound as was supposed. Even in the case of renewing bark the thickness of the renewal beneath the mixture is not greater than on untreated surfaces in the same time. Large wounds should not be covered with cowdung and clay, as the mixture does not prevent the entrance of borers, and it favours the decay of the wood. The only noticeable effect of cowdung and clay is that it keeps the stem moist. This can readily be seen in fairly dry weather when the stem of the tree is dry; if the mixture is then scraped off, the part covered by it will be found to be damp. On the majority of Rubber estates this is a disadvantage, but on estates in drier districts at a high elevation the application of cowdung and clay, by keeping

the stem damp, might prevent splitting of the renewing bark in the dry weather. It should not, however, be applied if any bark diseases are present.

Scraping

In the early attempts at rubber tapping, when the latex was allowed to run over the surface of the stem down to the base, it was recommended that the tree should be carefully and lightly shaved to obtain a perfectly smooth surface. This is no longer necessary, now that the latex is conducted to the collecting cup by a vertical channel, but the practice is still kept up on some estates, more with the idea of making the trees look tidy. It is now called "grooming" the trees.

There does not appear to be anything gained by this process, and in many cases it is distinctly dangerous. The outer corky bark is the natural protective tissue of the tree, and if it is scraped off the underlying cortex is exposed to the attacks of fungi until it has formed a new cork layer. In dry districts the new bark layer may take the form of thick scales. Serious attacks of Brown Bast have been known to follow this scraping, especially when the green layer of the cortex has been cut into. It is generally agreed that it is wrong to cut into the green, but in the majority of cases the cooly does, if he is given a knife.

It is certainly necessary to remove loose bark scales, and in the wetter districts it may be advisable to brush off the spongy layer on very corky-barked trees, but nothing should be removed which cannot be brushed off. For that purpose a piece of coir might be used, not a solid piece of coconut husk. Wire brushes should certainly not be used.

In Java it is said that Brown Bast may arise from superficial bark wounds, and, in consequence, it is recommended that the outer corky layer should not be scraped off, nor should patches above the tapping surface be smoothed, in order to inscribe data concerning the tapping, etc.

In experiments carried out by Sharples in the Federated Malay States, trees heavily scraped, the green layer being removed, were in several instances attacked by borers, while in one case this occurred on a tree lightly scraped, *i.e.* one on

which the green layer was left intact. The unscraped control trees were not attacked.

It is sometimes necessary to scrape trees, at least locally, to determine whether they are attacked by a bark disease, but gratuitous scraping should be avoided.

Forking

In some countries Rubber estates are periodically forked, or dug over, either in the course of manuring or applying lime, or as an independent method of cultivation. In Ceylon it is generally held that Rubber which is cultivated in that way responds by showing improvement both in growth and yield. In other countries this has been disputed, and it has been alleged that such treatment is not only useless, but dangerous, as it may give rise to root diseases. It is open to discussion whether it is advisable to apply horticultural methods to the cultivation of a forest tree. The effect of forking, carried out periodically for a number of years, would appear to be a suitable subject for investigation by an Experiment Station.

When *Hevea* attains a tappable age the ground is usually permeated with roots. The large laterals spread out from the base of the stem and branch repeatedly until they terminate in masses of fine white rootlets. In general the roots run not far below the surface. Consequently, in forking, large numbers of the smaller roots are broken. As the Rubber grows older the main roots increase in thickness, and thicker roots will be met with further from the stem.

The question then arises whether the fungus of a root disease, *e.g. Ustulina*, will attack the tree *via* the damaged or broken roots. From a general knowledge of the habits of *Ustulina*, it would not appear probable that that particular fungus would attack the smaller damaged roots, up to, say, one-eighth of an inch in diameter, but it is quite likely that it would attack the larger roots if these are in any way damaged or wounded. Hence it is advisable in forking young Rubber to keep well away from the base of the trees, and to increase the distance as the trees grow older. In old Rubber, forking, from a mycological standpoint, is not to be recommended.

Up to the present no cases of root disease have been

traced to injuries inflicted during forking. One effect has, however, been observed to follow frequent forking under certain conditions, viz. a general die-back of the ends of the branches over the whole of the crown of the tree. This occurred in the case of backward trees on poor quartzy soil. In such cases too frequent disturbance of the roots may produce an effect which simulates the early stages of a root disease.

Tree Surgery

Hitherto Rubber estates have usually carried too many trees to the acre, and consequently the removal of some of them through disease has been regarded as not involving any considerable loss. But when estates have been thinned down, probably to sixty trees to the acre, each tree will be proportionately more valuable, and it will be necessary to take all possible steps to preserve them. In the past the simple and easy plan of cutting out diseased trees could be adopted without any hesitation, but that cannot be carried on indefinitely, and the fewer trees there are the greater the efforts which must be made to keep them. It will then become a question of individual treatment in order to prolong the life of each tree to the fullest extent.

A somewhat similar problem has arisen in connection with the trees in gardens and public parks in large towns. Many of these trees were planted when the towns were small, and they cannot now be replaced because very few trees would come to maturity under the surrounding conditions. Hence, as far as can be done, endeavours are directed towards retaining the existing trees as long as possible, and in consequence there has been developed an art of tree surgery, or tree repair, several of the methods of which could be usefully applied to *Hevea*.

The practice which, it would appear, could be most profitably employed in the case of *Hevea* is that of filling up cavities in the stem. Such cavities may result in the upper part of the stem from improper pruning, or from wounds caused by branches being wrenched off by the wind, and at the base of the stem from a collar rot caused by canker or root disease. But whatever the cause, such cavities are gradually enlarged by the action of wood-rotting

fungi, until the stem breaks off or the tree is hollowed out and falls.

The idea of filling tree cavities is not a new one, but it is only comparatively recently that methods have been adopted which are likely to prove successful. Stopping tree cavities is analogous to dentistry, and two cardinal principles must be observed, viz. all decayed tissue must be cut away, and the filling must completely fill the hole, so that water cannot lodge behind it or fungus spores and insects obtain an entrance.

It is doubtful whether this method can be advantageously applied, in the case of *Hevea*, to large cavities in the upper parts of the tree. The wood of *Hevea* is brittle, and the excision of all the decayed tissue would probably weaken the stem to such an extent that it would break off. On the other hand, if such cavities are not treated, the stem will ultimately break off owing to the progress of the decay. In this respect prevention is better than cure; and more attention should be given to correct pruning and periodic tarring of wounds.

Cavities at the base of the tree, however, could safely be treated. All the diseased wood must be cut out; otherwise the fungi will continue to destroy the wood behind the filling. Successful treatment depends chiefly on the thoroughness with which the diseased wood is removed. It should then be painted with a coat of white lead paint and afterwards be filled solid. Creosote or Brunolinum, etc., followed by a coat of tar may be used instead of white lead paint.

Various mixtures are used for the filling. Bricks, stones, and cement is the most usual, the cement being mixed with two parts of fine sand. There should be no spaces left between the filling and the wood, and the outer face of the filling must be finished off smooth with the cement. The bricks and stones merely add bulk to the material: the lining next the wood should be cement, and the bricks, stones, etc., embedded in the middle of the cavity. After the filling has set it is left for a day or two, and then covered with coal tar to prevent cracking. The filling must not be brought level with the outer bark of the tree. What is desired is that the callus from the edges of the wound should grow over the cement, and either cover it completely or at least cover it

at the edges so that it holds it in position. Hence the filling should only be brought to the level of the cambium.

In the case of cavities in branches in which rain-water collects, care must be taken to see that they are quite dry before filling is attempted. If they are very deep, an auger hole should be bored into the branch to reach the base of the cavity so that any water will drain out.

On branches which are liable to bend and sway in the wind, a cement filling may crack and fall out. In such situations a mixture of asphalt and sawdust is used, in the proportion of one part of asphalt to four parts of dry sawdust. The sawdust should be from hard wood. The mixture is prepared by stirring the sawdust into boiling asphalt, and it is applied before it has cooled.

Cleaning up Forks

The bark at the main forks of *Hevea* usually becomes cracked and scaly. This is in part due to the increase in thickness of the tree and the mutual interference of the branches, and it may be assisted by the movement of the stems by the wind, and the flow of rain-water over the fork. The phenomenon is not a sign of disease in the cases hitherto recorded, and it is not in itself injurious, but the loose bark scales may afford a point of entry for a fungus. *Ustulina zonata* frequently attacks *Hevea* at a fork, and it is probable that its attack is facilitated by the presence of these loose scales.

A periodic cleaning up of these forks is practised on several estates, and it is especially to be advised where *Ustulina* is prevalent. The loose scales should be brushed off, and the fork painted with tar, or a mixture of tar and tallow. The latter is the more permanent, as the bark which is simply tarred scales off earlier; but it is a matter for decision on the estate whether it is cheaper to use tallow or to renew the tar when necessary.

CHAPTER II

ROOT DISEASES

When the roots of a tree are attacked by a fungus they are no longer able to perform their proper functions, and consequently the supply of water to the stem and leaves is cut off. The symptoms of a root disease are, therefore, purely secondary in the majority of cases, for it seldom happens except on large trees that the fungus has advanced above ground by the time the tree is dead, and the upper parts die from lack of water, not from an attack of the fungus on those parts. It follows that the symptoms of all root diseases are more or less the same, and especially on young trees are such as might be expected to follow if the trees were subjected to a prolonged drought. If the tree is a small one the leaves suddenly turn brown and dry up, and the tree usually dies with most of its leaves still attached; at the same time, the cortex dries and no latex exudes if it is cut.

Large trees may exhibit different symptoms at the beginning of an attack, though the final stages are generally the same. Part of the foliage may fall off while still green, months before the tree dies; this occurs especially in wet weather. Or the smaller branches may die back gradually, all over the crown, or especially in the upper parts, so that the tree becomes stag-headed. But in some cases the tree shows no signs of disease until it dies suddenly, or is blown over.

The difference between the effect on old and young trees respectively depends in general upon the extent to which the lateral roots have developed. Death is usually sudden in the case of young trees which have not acquired large lateral roots, but where the latter are present the tap root may be completely destroyed without any evident ill effect

upon the tree, and it is in these cases that the tree often shows no indication of disease until it is blown over. When trees are blown down root disease should always be suspected.

The differences in old trees depend also on whether the laterals or the tap root is first attacked. A sudden fall of leaves, dying back of small branches, and cessation of the flow of latex are often early indications of an attack of root disease on the laterals. These preliminary symptoms are rarer when the tap root is attacked, because the laterals are then still able to nourish the tree until the fungus reaches them in turn at the collar. But before that happens the tree in many cases falls in a moderate wind.

In the root diseases caused by *Ustulina* and *Fomes lamaoensis*, the first evident effect is in many cases a collar rot, *i.e.* the production of an area of decayed bark at the collar on one side of the stem, with a corresponding region of diseased wood behind it. This results from an attack of the fungus along a single lateral root. The fungus travels along the root to the stem, and there attacks the bark and wood immediately round the point of origin of the root. As both these diseases progress rather slowly, this rot may be well advanced before any effect is observable in the crown.

Except in young trees, the effect of a root disease on the flow of latex is highly variable. In the case of *Fomes lignosus*, cessation of the latex flow has been known to result from an attack on the laterals, eight months before the tree was evidently dying. On the other hand, when the tap root has been destroyed, trees have yielded latex until they were blown down. In the root disease caused by *Ustulina*, it has frequently been noted that the trees attacked yielded an abnormally large quantity of latex for some weeks just before they succumbed. These differences are of the greatest interest, especially in view of the theory that the roots constitute a reservoir of latex, and further observations on this point are desirable.

Root diseases of Rubber are sometimes divided into Wet Rots and Dry Rots, according to the character of the diseased wood; but while this classification may be feasible in some countries, it is likely to prove misleading if transferred to others. In Malaya the term "Wet Rot" is applied to the rot caused by *Fomes pseudo-ferreus*, but in Ceylon the

wettest rot is usually that caused by *Fomes lignosus*. Brown Root disease may be either a wet or a dry rot according to external conditions.

Similarly, the term "Heart Rot," signifying that the fungus attacks the heart wood in preference to the sap wood, cannot be confined to any particular disease. On underground roots, the known root disease fungi usually attack the whole root; but when the fungus advances upwards it frequently travels up the stem more rapidly in the heart wood, and causes a conical decayed or diseased region. This occurs quite commonly in Brown Root disease and *Ustulina*, and it is not uncommon in the case of *Fomes lignosus*.

For several years it has been customary at Peradeniya to develop the fungus, whenever possible, from any *Hevea* roots which present any feature varying from the typical characters of the known root diseases. One frequent phenomenon in diseased roots is the occurrence of a broad, rusty-coloured zone in the wood bordering on the decayed region. For example, when a root which ran along the surface of the ground has been attacked on the lower side, it is often hollowed out half-way through from below, and the decayed region may be bordered above by the zone described. Or it may occur in a stem when the rot is advancing upwards. In some cases such specimens have produced *Fomes lignosus*, in others, *Ustulina*. Hence the discoloration is not typical of any one disease.

In general there is little hope of saving a tree which is attacked by a root disease. At least in the majority of cases, the first tree discovered at any centre of disease is usually beyond recovery. But trees may be detected in an early stage of the disease round a dead tree, or round a known disease patch, and these may constitute exceptions to the general rule.

The treatment of root diseases involves the removal of all dead trees, decaying stumps, and timber in the affected patch, the isolation of the patch by means of a deep trench, and the application of lime to the soil. It is now generally recognised that decaying stumps and timber are the source of root diseases in general, and it is of little use to dig out and burn the dead tree and leave the stump from which the fungus has spread.

The first operation should be the removal of the dead tree. This should be cut down if it has not already fallen, and as much as possible of the roots dug out. The laterals should be followed up and dug out, especially if they are diseased. *Neglect to follow up the laterals is one of the chief causes of failure in treating root diseases.* Any piece of a diseased lateral is capable of communicating the disease to a healthy root which happens to come in contact with it. The upper parts of the tree can be taken for firewood, but the diseased roots, and any neighbouring jungle stump, or decaying logs, should be burnt on the spot. The affected patch should then be forked over, and all pieces of dead wood collected and burnt.

The object of trenching is to isolate the patch which is known to contain the mycelium of the fungus, and to sever all communication between the roots in that patch and the roots of surrounding trees, so that the fungus cannot spread outwards along the roots over a wider area. The position of the trench is consequently governed by the distance to which the diseased laterals extend. In any case, the trench should enclose not only the diseased tree, but also a complete ring of the surrounding trees, even though the latter are apparently healthy. Having decided upon the position of the trench, the ground should then be limed before the trench is cut.

The majority of fungi prefer an acid medium. Hence the application of lime, which makes the soil less acid, produces a condition which is less favourable to fungus growth. In Ceylon it is usual to apply lime to root disease patches at the rate of sixty pounds for each dead tree or stump, with the addition of fifteen pounds for each living tree which is to be enclosed within the trench. In Malaya, twenty-five pounds for every hundred square feet is recommended. The lime is to be scattered over the affected patch, not merely in the trench, and special care should be taken to see that it is applied liberally along the lines of the lateral roots. As it is desired to apply the lime to the soil in which the fungus grew, it is better to make the application before the trench is dug, otherwise one is in a great measure merely liming the excavated soil, especially if the patch is a small one. After the lime has been scattered over the soil, it should be forked in.

The depth of the trench should, as a rule, be about two feet, but in some soils it may have to be more. The trench should sever all lateral roots, and though in general this is effected by the depth stated, I have seen instances in deep, loamy soil, where the lateral roots of a jak tree, one of the worst sources of *Fomes lignosus*, ran horizontally at a depth of three feet. The quantity of soil to be disposed of is, however, so large when the trenches are deep, that they should not be carried down to a depth of three feet unless that is absolutely necessary. The soil dug out is thrown inwards on the affected patch, not on the outer edge of the trench. Where the mycelium occurs on the under side of stones of moderate size, these should be turned over so as to expose it to the sun and sprinkled with lime.

It is now becoming customary to open up and examine the roots of the trees which are included within the isolation trench, in order to determine whether they have already been attacked. It is of course impossible to follow up the roots to their extremities, but enough can be done to show whether the tree is seriously affected. The roots should be exposed for a radius of about three feet from the stem, and the tap root to a depth of about two feet. The operation requires great care, especially in rocky soil where large stones are wedged between the roots. Indeed, the examination in such cases often causes so much damage that its value is doubtful. Any attempt to use the root as a fulcrum to lever out stones generally results in breaking away large areas of cortex. In one case where this examination was carried out over an area of a hundred acres, infested with *Fomes lignosus*, it was found that a cooly could not open up more than two trees per day, if excessive injury was to be avoided. All wounds caused should be tarred.

If upon examination the tap root is found to be decayed, the tree should be removed. If the fungus is found advancing towards the collar on one or two laterals, these may be cut back into sound tissue, and the diseased laterals dug out. It must be borne in mind that the mycelium usually travels along the under side of the laterals, especially when the upper side is exposed; this is particularly so in the case of *Fomes lignosus*. In the latter disease, the external strands of mycelium fairly frequently extend over the surface of the

root in advance of the penetration of the fungus. The part covered by the youngest mycelium may consequently not have been attacked, or only attacked to a slight depth. In such cases, the mycelium and any underlying decayed bark and wood may be cut away and the wound treated. This method is especially useful when the tap root only has just been attacked. In Ceylon it is usual to dress the roots from which mycelium has been scraped off with Brunolinum, or tar, while in the Straits Settlements, Bordeaux paste has been used. It must be remembered that the mycelium travels inside the root as well as on its surface, and consequently, if the decayed parts of the root are not cut away, any treatment is useless. The method is said to have been attended with great success, trees which bore the mycelium of *Fomes lignosus* having been completely cured. There is, however, probably an element of doubt in some instances, owing to the possibility of a mistake in the identification of the mycelium. Loose, white, or bluish-white mycelium is fairly plentiful in soils which contain dead leaves, twigs, etc., as is usually the case on a Rubber plantation, and in general this is merely saprophytic. Such mycelium is frequently found in the soil round the base of a Rubber tree, and is often mistaken for that of *Fomes lignosus*. In identifying *Fomes lignosus*, only the stout mycelium adherent to the root can be relied on.

The foregoing method is likely to be of service in cases of Brown Root disease and *Ustulina*, since, where these diseases are known to be prevalent, many cases can be discovered when only one lateral root has been attacked. Both these diseases progress comparatively slowly, and even when the fungus has penetrated into the stem round the lateral root, it may yet be possible to save the tree by cutting away all dead wood. The cavity should then be tarred and filled up with concrete (see p. 19).

The holes round the trees examined may be left open for a week or two in fine weather, but if there is any danger of water collecting in them they should be filled up as soon as possible. Where cavities have been filled with concrete, the filling should where possible be left exposed; this could be done on a hill-side, where a channel could be cut so that water might drain off, but on level land the earth should be levelled up so that water will not lodge against the filling.

Over areas which are known to be more or less generally infected with a root disease fungus, such as old Cacao land where Brown Root disease is spreading from the Cacao stumps, old Tea areas where *Fomes lignosus* is developing on the abandoned Tea, and other similar cases, the whole area should be limed at the rate of at least a ton per acre, after the removal of the decaying stumps of the previous cultivation or intercrop.

Six root diseases of *Hevea* have been recorded up to the present. These may be distinguished in most cases by the following characteristics :

White, or yellowish, or reddish strands on the exterior of the root . . .	*Fomes lignosus.*
Red smooth strands, or red sheets, which become black : with red or brown lines in the wood	*Poria hypobrunnea* (Red Root disease).
Sand and stones cemented to the root by fine tawny-brown mycelium : brown lines in the wood	*Fomes lamaoensis* (Brown Root disease).
Inner bark decayed and collapsed, so that the outer bark is easily removed ; frequently (not always) a tough skin-like dark brownish-red mycelium bound up with the outer cork layers of the bark	*Fomes pseudo-ferreus.*
No external mycelium, or with a few black projecting points : white fans of mycelium between the bark and wood : black lines in the wood . . .	*Ustulina zonata.*
No external mycelium : red or black strands between the bark and the wood	*Sphaerostilbe repens.*

Fomes lignosus, Klotzsch

(*Fomes semitostus*, Auctt., non Berk.)

This disease is the most widely-known root disease of *Hevea*, partly because it was the first to be discovered, but principally because of the serious loss it has caused in many localities. It was originally recorded under the name of *Fomes semitostus*, and in most of the literature relating to it that name has been employed, but it has since been found that

the original *Fomes semitostus* is quite a different fungus, and that the correct name of the species which causes this Rubber root disease is *Fomes lignosus*.

Fig. 1.—*Fomes lignosus*; mycelium on root. × ¼.

The disease was first discovered by Ridley at Singapore in 1904. In Ceylon it was first recorded in 1905. The absence of any previous record in Ceylon is doubtless due to the fact that much of the earlier Ceylon Rubber was planted among Tea or Cacao, and that some of the earliest plantations were established on land which had been cleared of almost all the jungle stumps prior to planting.

Since 1905 this disease has been found to be fairly general in the Ceylon Rubber districts, and there are few estates which cannot show a *Fomes* patch; while in some cases it has caused considerable loss of trees and a large expenditure on methods of treatment. In Malaya it is known as the commonest root disease of *Hevea*, and large sums have been spent on its eradication. It occurs in South India, Java, Sumatra, and Borneo, and in West Africa and the Congo region. The disease does not appear to have been recorded from the Western Hemisphere, but as the fungus is known to occur throughout the tropics, it will no doubt ultimately be found to attack *Hevea* wherever it is grown.

As a rule this disease is readily identified by the mycelium on the exterior of the roots. This takes the form of stout smooth cords firmly attached to the bark, running more or less longitudinally along the root, and uniting here and there to form a network (Fig. 1; Plate II., Fig. 4). These cords

may be white, or yellowish-white, or reddish. They vary in breadth up to a quarter of an inch, and may spread out here and there and unite into continuous sheets. In general they are more or less rounded on the upper side, and consequently stand up above the level of the bark. The younger growing parts are white and soft, and often branch in a radiating or fan-like manner (Fig. 2). Such immature cords are often found at the collar. It is rare that the mycelium extends up the stem above ground. When it does the strands usually divide into finer threads, or separate hyphae, which can only be detected with difficulty among the rough bark at the base of the stem. This, however, in general, only occurs when the tap root has been almost completely destroyed.

On trees in normal situations, the depth of the tap root which is covered by the mycelium may be as much as thirty inches, but where a tree is growing near a bank, or by the side of a deep drain, it may be much greater. The external mycelium gives rise to threads which penetrate into the tissues of the root and bring about their decay; and the whole of the wood and cortex is ultimately permeated with fine fungus threads which render them soft and friable. The type of rot varies, but in Ceylon the decayed wood is very often wet and sodden. It is not notably discoloured, and the bark has the normal brown colour of dead bark internally.

A different appearance has been observed on several occasions in Ceylon, usually in the drier districts. In these cases the tap root did not show any external strands, but appeared blackish and sodden, and on removing the bark the wood was found to be decayed and watery, with short white lines of mycelium embedded in the surface. The fructification was subsequently developed from the diseased tap root and the identity of the disease determined. The lateral roots often bore the normal cords of mycelium, and it would appear that in these cases the fungus, after attacking the tree *via* a lateral root, proceeds down only inside the tap root.

In general the fructification of the fungus will seldom be found on trees which have been killed by this disease; it can only be formed above ground, and as a rule the mycelium has not reached the surface by the time the tree is dead or has been blown over. Exceptions to this rule may occur in the

case of trees growing on land which is subject to periodic inundation, and I have seen the fructification at the base of a *Hevea*, not yet dead, which happened to be growing, neglected, in a patch of scrub. Possibly the production of fructifications before the tree is dead may become more general when older trees are attacked. Of course, if a dead tree is left standing for some months, the fructification will ultimately develop at the base unless prevented by white ants; and if a fallen tree killed by *Fomes lignosus* is allowed to lie and decay, the fructification will similarly be developed along its whole length. But under ordinary estate conditions, where a diseased tree is discovered before, or as soon as it has died, neither the stem nor the root will show any sign of a fructification, at least in the case of trees up to twelve years old.

In new clearings and young plantations, it is usually possible to find the fructification of the fungus on a decaying jungle stump near the trees attacked, and this continues to be the case as long as the stumps remain. Where *Hevea* has been felled in thinning out, and the stumps left, the fructification may be found on the latter, and the same holds good for Cacao stumps. In fact, in the most general case, the disease spreads to the Rubber from a decaying stump of some kind, and the fructification is usually present on the stump from which the disease originated.

The fructification (Plate I.; Plate II., Fig. 1) first appears as a small orange-yellow cushion. This grows out horizontally into a flat plate, more or less semicircular in outline, attached to the stump along its hinder margin. In general, this plate is up to four inches in diameter, but in favourable situations it may be as much as a foot. It is about half an inch thick behind, and thins out regularly towards the margin. From their shape fungi of this class are known as bracket fungi: many species occur quite commonly on decaying logs and stumps, but the majority of them are harmless.

Fomes lignosus is identified by its colour, but the colour varies enormously according to the age of the fungus and the amount of moisture in it. At first the bracket is a rich red-brown on the upper surface, with a bright yellow margin, while its lower surface is bright orange. If it dries in that stage, the red-brown colour of the upper surface gradually

disappears, not uniformly all over, but in concentric zones, so that it becomes banded with broad alternate zones of red-brown and yellow-brown. When fully developed, it is still red-brown, but paler than in the earlier stages, and is marked with fine, concentric, darker red-brown lines; at the same time it loses its orange margin, and the lower surface becomes red-brown (Plate II., Fig. 2). When old and dry it is pale yellow-brown or wood colour, with concentric darker lines.

The upper surface is not quite smooth, but bears numerous concentric grooves parallel to the outer edge. Fine radiating striae run at right angles to these grooves, and give the surface a silky appearance. The lower surface is studded with minute holes, or pores, which are the openings of the tubes in which the spores are produced: these holes are very small, and scarcely visible without a lens.

The substance of the fructification is somewhat woody, but it can easily be broken. The internal tissue consists of two layers, which differ from one another in colour and structure (Plate II., Fig. 3). The upper layer is white and fibrous, the fibres running more or less parallel to the surface, but the lower layer is red-brown, and consists of tubes, closely packed side by side, and perpendicular to the lower surface. In old specimens there may be two or more layers of these tubes. When the fructification dries, the outer edge curls downwards and backwards over the lower surface.

When the fungus is allowed to luxuriate unchecked, these brackets grow one above the other for a distance of two or three feet, united behind by a continuous orange-yellow cushion. At the same time fresh plates are produced at the sides of the old ones, and these fuse with the latter and make the edge of the brackets more irregular. Such masses of brackets may extend along fallen logs, or along the lateral roots of jungle stumps for several yards (Plate I.).

When growing on the under surface of a log, and sometimes also in other situations, the fructification of *Fomes lignosus* may take the form of an orange or red-brown plate, spreading flat over the surface and closely adherent to it, instead of the usual bracket shape. This is known as a resupinate or *Poria* form (Fig. 2).

There is a very common fungus which is frequently mistaken for *Fomes lignosus*, and, indeed, in the dry state

it is scarcely distinguishable from it. When dry it is pale

FIG. 2.—*Fomes lignosus*; young mycelium and resupinate fructifications. × $\frac{2}{3}$.

yellow-brown, with narrow red-brown concentric zones. It

is usually smaller than *Fomes lignosus*, and deeply grooved both radially and concentrically. Like *Fomes lignosus* it curls up as it dries. When fresh, however, it is fairly easily distinguished. It is never so red-brown, and it does not have an orange margin. The lower surface is usually a dingy, livid grey, though it sometimes becomes red-brown. The best way of identifying it is to break it in two; it is then seen to be uniformly white internally, both in the fibrous layer and the tubes, whereas *Fomes lignosus*, as already stated, shows two colours in section. This species is *Polyporus zonalis*, Berk. It is common on dead wood, especially on palms and bamboos, but is merely saprophytic. It has the same power as *Fomes lignosus* of spreading through the soil and producing its fructification on anything it happens to meet. I have seen it in abundance on living roots of Rubber as well as on bricks in a rubbish heap: in both cases the mycelium had spread from buried decaying wood.

As a rule *Fomes lignosus* makes its appearance in a new clearing when the trees are one to three years old. This is a consequence of the manner in which the disease originates. In the majority of cases, the fungus first develops upon a neighbouring stump. The spores of the fungus blown by the wind alight on the dead stump, and there give rise to a mycelium which permeates the dead wood and brings about its decay. After some time, when the dead wood has been more or less destroyed by the fungus, the mycelium spreads along the lateral roots, or through the soil, and if it comes in contact with a *Hevea* root, it grows round and along it, giving off fine threads which penetrate into the wood and ultimately destroy it. Thus, the time when the disease is first evident on the Rubber depends to a great extent upon the time taken by the fungus to destroy the jungle stumps, or perhaps more correctly, on the time taken by it to accumulate to such a degree that it is able to spread further afield. It may also be dependent upon the time taken by the Rubber to develop lateral roots, since the fungus will then have a shorter distance to travel to reach them. It is not, however, necessary that the lateral roots of the Rubber should come in contact with the diseased roots of the stump, because the mycelium of *Fomes lignosus* can travel independently through the soil.

It is the fact last mentioned which makes this disease so formidable, and makes its eradication so difficult. The majority of fungi only advance within dead wood, but the strands of *Fomes lignosus* can travel for a few feet at least through the soil, unattached to any root or dead wood, except, of course, at their starting-point. It is always attached to its base, *i.e.* the stump on which it originated, and it must derive its food from that source until it meets with other dead wood, or a living plant which it can attack. In all probability it will die if separated from its base, unless it soon meets with fresh material from which it can derive nourishment.

Clear instances of the spread of the mycelium through the soil are not uncommonly met with on estates. In badly-infested areas its presence is often manifested by the appearance of the fructifications on banks by roadsides, or the sides of drains, where no roots or timber is to be seen. In some of these cases the mycelium follows small Rubber roots almost to the surface of the soil, but in others there is no root or wood to be found immediately behind the fructification. In other cases it is often found running on the under surface of large stones, and in these instances it is readily seen, as a rule, that it is not following a root. The best examples of this are usually to be observed on hill-sides which have been terraced with stones. The mycelium then runs more or less parallel to the surface of the soil, and consequently meets the wall, where it covers the stones with its characteristic strands and often produces fructifications on the outer side. It may be noted that this is not an objection against terracing, since the wall to some degree stops the spread of the mycelium. Had the hill-side not been terraced, the mycelium would have spread down the slope.

Free mycelium is usually found in the uppermost foot or eighteen inches of the soil, but the mycelium which runs along a root will follow the latter to greater depths. On laterals which are exposed on the surface of the soil, the mycelium travels along the lower side. The disease appears to spread downhill more rapidly than up; and when it occurs in ravines it generally spreads in the direction of the flow of the stream.

As already pointed out, this disease, in the majority of

cases, is due to the presence of decaying stumps. In young plantations these are, of course, the jungle stumps which were left when the land was cleared. When *Fomes lignosus* was first found in Ceylon, it was most frequently associated with stumps of either Jak (*Artocarpus integrifolia*) or the various species of *Ficus*. Hence it was presumed that it would be unnecessary to remove all stumps in order to avoid the occurrence of this disease, but that it would be sufficient to adopt a selective method of stumping and to get rid of the stumps of these trees which were known to serve as hosts for the fungus. In Malaya the conditions proved to be quite different. Gallagher recorded the finding of the fructification in that country on a Serdang stump, *i.e.* a palm (*Livistonia cochin-chinensis*), and stated that the disease had been known to spread from stumps of Meranti (*Shorea* sp.) and Merbau (*Afzelia palembanica*). Bancroft added that he had frequently found the fructification on the stumps of another palm, the Nibong (*Oncosperma filamentosa*), as well as on stumps of bamboos and of the Kumpus (*Koompassia malaccensis*); he concluded that the fungus occurred indiscriminately on all kinds of stumps.

Further investigations in Ceylon support the conclusions reached in Malaya. The disease has been found to originate from stumps of Tea, Cacao, Bombax (*Bombax malabaricum*), and the Bois Immortelle or thorny Dadap (*Erythrina umbrosa*), while the fructification has occurred on dead stumps of the giant bamboo (*Dendrocalamus giganteus*). The fungus has now been recorded in that country as the cause of root disease of Tea, Halmilla (*Berrya ammonilla*), *Derris dalbergioides*, Ceara Rubber, and the Coconut palm; and in Malaya it has killed Cassava, Camphor, Liberian Coffee, and *Coffea robusta*. The records cover such a wide range of flowering plants that any selective method of stumping is impossible. To avoid the attacks of *Fomes lignosus* all stumps must be removed.

In Ceylon the eradication of jungle stumps on Rubber estates has now been fairly generally carried out. It is not, however, to be expected that, where the stumps have been allowed to remain for several years, their removal will immediately put an end to all further loss from this disease. In many instances the old, known *Fomes* patches have not

been thoroughly treated and continue to give trouble, while new cases may be expected to occur during the next two years as the result of infections which had not produced any visible effect at the time the stumps were taken out. But the principal outbreaks of this disease in Ceylon in recent years have not been due to jungle stumps, but to the following sources.

As is well known, the majority of Rubber estates were originally much too closely planted, and it became necessary to thin out. In general, estates followed the course which had been advised, and uprooted the condemned trees, or at least extracted the tap root to a depth of two feet or so. In some cases, however, the trees were cut down at ground level, and the stumps left to rot, with the consequence that not only *Fomes lignosus*, but other root disease fungi also developed on these stumps, and they accordingly became centres of disease.

Similar results followed on mixed Rubber and Cacao estates where the Cacao was simply cut down when it had to be removed. In general, the root disease which develops from Cacao stumps is Brown Root disease, but in several instances *Fomes lignosus* occurred.

One unexpected result was the occurrence of attacks of *Fomes lignosus* after the abandonment or incomplete removal of Tea. It had been recommended that abandoned Tea should be uprooted in order to minimise the possibility of attacks of *Ustulina zonata*, or *Botryodiplodia Theobromae*, both of which were known to attack Tea, but as *Fomes lignosus* had never been noted as the cause of root disease in Tea, the latter was not anticipated. It has, however, since been found that *Fomes lignosus* can attack Tea, and several instances have been recorded in which this fungus has developed on abandoned Tea, and spread to the interplanted Rubber. The worst case, however, was one in which the Tea had been cleared by merely cutting it off at ground level and leaving all the roots to decay. The majority of the stumps were affected, and, as Tea bushes are planted only four feet apart, the ground became thoroughly permeated with the mycelium of the fungus, an area of about a hundred acres being involved. The fructifications of the fungus appeared everywhere, on Tea stumps, dead wood, roadside

banks, and drain sides. A trench was dug round the whole area, but trenching round individual infected patches was impossible, and, instead, trenches were dug round groups of apparently healthy trees. Dead trees, or trees which had lost their tap roots, were removed and burnt, and the roots of all trees examined, and treated when necessary, while the ground was limed with a general dressing of 2000 pounds of lime per acre, in addition to 60 pounds for each dead tree. A fair proportion of the trees were saved by these methods.

Another unexpected development of *Fomes lignosus* over a large area followed the operations attending the removal of large examples of the thorny Dadap (*Erythrina umbrosa*). The estate had been originally in Cacao, through which the dadaps had been planted as shade trees. Subsequently it was interplanted with *Hevea*, and when the latter grew up it was decided to take out the dadaps, which were then about thirty years old. They were accordingly ringed at a few feet from the ground and left to die. In about five years' time the trees began to fall, and shortly afterwards *Fomes lignosus* was found to have developed in abundance not only on the stumps, but also along the fallen trunks.

It will be evident from the examples given that from the point of view of root disease it is unsafe to leave stumps of any kind among rubber.

The symptoms exhibited by trees attacked by *Fomes lignosus* differ, apparently, according to the part attacked. Sometimes the laterals are first attacked, sometimes the tap root, but which of these happens is purely a matter of chance. When the tap root only is attacked it is frequently completely decayed before the trees show any symptoms of disease. In one of the earliest cases recorded in Ceylon nothing was observed to be wrong with the trees until seven hundred, on an area of about eighty acres, blew over in one night. It was then seen that in every case the tap root was decayed, and the trees had been supported only by the laterals. When the tree is not blown over the fungus gradually ascends to the collar and attacks the laterals near their base, and, in consequence, the tree dies more or less suddenly. Trees which have lost their tap roots can sometimes be recognised by the shape of the lower part of the

stem, which often becomes fluted. When the tap root has been destroyed, the increase in girth is apparently greatest over the main lateral roots, so that a vertical ridge is developed on the stem above each of them. This appearance often proves useful in the detection of diseased trees round one which has already succumbed.

When the attack begins on the laterals the smaller branches may die back generally, *i.e.* all over the crown, and the tree become stag-headed some months before it dies. This is another appearance by which diseased trees may be detected round a known *Fomes* patch, but it is not universally a sign of root disease. Sometimes the leaves turn yellow before the branches die back. In other cases an extensive fall of leaf occurs, especially in wet weather. In some cases the flow of latex ceases in an early stage of the disease, while in others it continues until the leaves turn brown and the tree dies. If only the laterals on one side of the tree are attacked, very little may be noticeable for a long time.

In the following instance the course of the disease was watched almost from the beginning. The tree, which was one whose yield per tapping was being recorded, shed part of its foliage during wet weather in August and ceased to yield latex. The tap root and the laterals for a distance of two or three feet were examined, but no *Fomes* mycelium was observed. The tree continued dry until the following February, when it wintered and produced new foliage. It then yielded latex for a few weeks, but soon went dry again, and the new foliage at the tips of the branches began to turn yellow. When the roots were examined again in May, *Fomes* mycelium was found on the laterals advancing to within a short distance of the stem. Thus the effect of the disease had been manifested by the fall of the leaves and the cessation of the latex flow, about nine months before the mycelium had travelled along the laterals far enough to be discoverable by the methods usually employed.

In contrast to the foregoing, a tree in the neighbourhood of an old-established *Fomes* patch has been found to have all its laterals covered with a network of mycelium, without showing any die-back in the crown, or falling off in the yield of latex.

It is scarcely possible to give any definite estimate of the time which elapses between the beginning of an attack and the death of the tree, as so many different factors may influence the course of the disease. Young trees may be expected to succumb more quickly than old trees. The growth of the mycelium is to some extent dependent on climatic conditions, and it is not necessarily most rapid in swampy land. The effect will differ also, as already pointed out, according to whether the laterals or the tap root is first attacked. Observations in Ceylon would appear to show that the presence of the disease is manifested earliest when the laterals are attacked first. Taking all circumstances into consideration, it is probable that the majority of the trees attacked die within twelve months.

Though infection from a dead stump is the most usual way in which *Fomes lignosus* attacks *Hevea*, it is to be expected that, as the fungus is parasitic on *Hevea*, cases will occur in older Rubber through direct infection by means of spores, more especially on exposed or injured lateral roots. One case, at least, which could not be explained on any other supposition, has been noted in Ceylon. The tree was twelve years old, and was growing in Tea twenty-five years old. All jungle stumps had long since disappeared, and there was no root disease on the surrounding Tea. Such cases are, however, rare.

Infection by spores has been considered improbable, because, when the fructifications have been examined, they have been found to bear very few spores, or in some cases none at all. This is probably merely a matter of examining the fructifications at the right stage. There can be no doubt that under "wild" conditions the dissemination of the fungus to different centres is effected by spores, and, indeed, its occurrence on Cacao stumps on old Cacao estates, on Rubber stumps after thinning out on previously clean areas, and on abandoned Tea some twenty years old is clear evidence of spore infection. Many other similar cases are available. It occurred, for example, on the roots of the famous row of *Ficus elastica* at the entrance of the Peradeniya Gardens, when these were felled at the age of about eighty years, though the surrounding area had been cleared for the same period; and it similarly developed at Peradeniya

on the stumps of Giant Bamboos (*Dendrocalamus giganteus*) which died after flowering at the age of about fifty years. Moreover its occurrence on jungle stumps in new clearings can only be explained by spore infection, for it is quite contrary to all experience in field mycology to suppose that all such stumps were attacked by *Fomes lignosus* before the jungle was felled.

In Malaya this disease is said to be worst on clayey soils or on peaty land. On the latter it is frequently very difficult to eradicate, owing to the presence of buried logs. Thorough drainage is of the greatest importance in both cases.

The treatment of *Fomes lignosus* follows the usual lines of digging out and burning diseased roots and all dead stumps or rotting timber, liming the patch, and surrounding it by a trench (see p. 24). It is very important that the diseased laterals should be followed up as far as possible and lime scattered especially along their path. Lack of success in treating *Fomes* is frequently due to neglect of this point. Another cause of failure is the unwillingness of the planter to put the trench far enough away from the original dead tree. By the time one tree has died the lateral roots of the surrounding trees have in many cases been attacked, and if these have not been isolated the disease will in all probability have travelled a row farther on before they in turn die. The trench should always be cut so as to include the four nearest trees, even if the latter appear quite healthy. Many estates practise double trenching, especially where more than one tree has died. The first trench encloses the dead trees and those immediately round them, while the second is dug a row outside the first. The ground should be forked over, and all dead wood and diseased roots removed as far as possible before the trenches are dug; otherwise they are buried beneath the excavated soil. It is not uncommon to find roots about the thickness of a pencil covered with mycelium, and often producing fructifications, in treated *Fomes* patches.

It is often possible to pick out diseased trees round a *Fomes* patch by a fluting at the base of the stem, or a general die-back of small branches all over the crown. The roots of such trees should be opened up and examined, and if they are badly attacked, or if the tap root is decayed, they should

be removed immediately. The lateral roots can be laid bare for a distance of about three feet from the stem, and the tap root to a depth of two feet, without endangering the stability of the tree. All trees enclosed within the trench should be examined in this way. If only one or two laterals are decayed, these may be cut back into sound tissue and the wound tarred. In some cases, where the disease has only just attacked the roots, it has been possible to treat them by scraping off the superficial mycelium and painting them with Brunolinum or other preservatives, or even with tar. This possibility depends on the fact that the superficial mycelium frequently spreads for some distance along a root before penetrating it. But if the bark and wood beneath the mycelium is attacked, either the diseased part or the whole root must be cut out.

It is necessary to inspect *Fomes* trenches periodically to see whether the fructifications are developing on the sides. These should be removed and any dead wood from which they are growing dug out. If they develop on the outer wall of the trench, it is a sign that the trench has not been made far enough away, and it must be extended by a loop on that side which should include at least the next tree.

Brown Root Disease

(*Fomes lamaoensis*, Murr.)

This disease appears to be the most widely-spread root disease of cultivated plants in the Eastern Tropics. It was apparently originally found on Bread-fruit trees in Samoa, where it was said to cause very serious damage. The next report of it was on Tea in Northern India : in this case the principal features of the disease were described by Cunningham, and though he did not discover what the fungus was, it is clear from his description that he was dealing with this disease. Similarly, Zimmermann found it attacking Coffee in Java, but was unable to ascertain the identity of the fungus which caused it.

It was first recorded on *Hevea* in Ceylon, and it is probably the commonest root disease of the Rubber tree in that country. Yet, except under special conditions, it does not cause so much damage as *Fomes lignosus.* The latter can spread

independently through the soil from a jungle stump, and may attack a number of trees in one spot before any of them is so seriously affected as to show signs that there is something amiss. Brown Root disease, on the contrary, spreads very slowly, and, for all practical purposes, only along the roots of the tree; consequently it only infects the neighbouring trees when their roots are in contact with those of the diseased tree, and the progress of the fungus is so slow that, as a rule, the first affected tree is dead before the neighbouring trees are attacked. In general, therefore, only one tree is killed at each centre of infection, unless the dead tree is left standing for a long period.

FIG. 3.—*Fomes lamaoensis*; mycelium on root. ×½.

When the dead tree is dug up, the special characters of Brown Root disease are usually immediately evident, and, as a rule, there can be no mistake in the diagnosis. The roots (Fig. 3) are encrusted with a mass of sand, earth, and small stones to a thickness of three or four millimetres; this mass is fastened to the root by the mycelium of the fungus, and, consequently, cannot be washed off. The mycelium consists of tawny brown threads, which are collected here and there into small sheets or loose masses, either on the surface, or embedded in the crust of soil and stones. The colour of the mycelium varies, and one frequently finds brownish-white, or almost white, masses intermingled with the tawny brown. In the early stages the predominating colour of the mycelium is brown, and this is usually the case when the

roots of a dead tree are examined. Hence the name Brown Root disease. But when the disease has been established for a long time, and the fungus has grown older, it forms a black, brittle, continuous covering over the brown masses of hyphae, and the diseased root then appears chiefly black. The brown mycelium is, however, immediately discernible if the black crust is cut.

In all stages the encrusting mass of earth and stones, intermingled with brown threads, serves to distinguish this disease. The root looks as though it had been dipped in glue and then had soil and stones scattered over it. Bancroft stated that the surface of the root becomes dark brown and almost black, and for that reason the coolies in Malaya know the disease as " Sakit hitam."

In the case of young trees the encrusting mass is usually most strongly developed on the tap root, and it may ascend up the stem for several inches. On old trees, however, the appearance may be different, especially if the tap root is the part first attacked. In that case, owing to the slow effect of the disease, the tap root may be in an advanced stage of decay, before the fungus has spread to the laterals sufficiently to cause any marked symptoms in the crown. The cortex with its covering of earth and stones may by that time have disappeared completely from the tap root, owing either to decay or to the attacks of white ants, and it is then necessary to examine the laterals to find the characteristic external appearance of the disease. But even when the outer crust has disappeared the disease may usually be identified by the appearance of the wood.

In some cases, after the tap root has been attacked, the tree produces new roots at the collar, and these grow down vertically and take the place of the missing tap root. As Bancroft has pointed out, this is an indication of the slow progress of the disease. I have, however, seen the same thing in a case of *Fomes lignosus*, where the disease had for some unknown reason been arrested after the tap root had been destroyed.

If the encrusting mass is cut away, the cortex on the diseased roots is found to be brown, or brown mottled with small white patches internally. The diseased wood usually shows characteristic markings, though these may be of two

entirely different types. In the one case the wood is soft and friable, with a network of fine brown lines (Plate II., Fig. 7), and even with a hand lens it can be seen that these lines are composed of brown hyphae. Thin sheets of brown hyphae run through the decaying wood, and these appear as brown lines when the wood is cut. This is the more frequent appearance in the lateral roots. In the other case the wood of the root is comparatively hard, and traversed by rather broad brown bands (Plate II., Fig. 8), in which no hyphae are discernible. This may occur in the lateral roots, but is more usual at the base of the stem. There is some evidence that the appearance first described follows the second. In either case the wood in an advanced stage of decay may be honeycombed, the brown plates persisting after the tissue between them has almost completely decayed.

A few narrow black lines are usually present in the diseased roots, but the brown lines are more numerous. In advanced cases, black circles are sometimes found when the cortex is stripped off a diseased root.

Brown Root disease, in its most general form, might be regarded as a "dry rot," but I have seen advanced cases where the honeycomb structure was well developed, in which the cells of the honeycomb were filled with water.

This disease often appears on old trees as a "collar rot," *i.e.* an area of rotten, decayed bark, more or less triangular in outline, and broadest below, extends upwards from ground level on one side of the stem for a height of a foot or so. The wood behind this region is decayed and rotten, and may weather away, leaving a large cavity at the base of the tree. This effect is produced by an attack of the fungus on a lateral root, and its advance along the lateral to the base of the stem, which is attacked round the point of origin of the lateral. This mode of attack is very common in cases where the fungus first develops on Cacao stumps and spreads from them to the *Hevea*; and in such cases it is easy to pick out the affected trees by the rotten patch of bark at the base, before any effect is observable in the crown. *Ustulina zonata* frequently works in the same way.

When the fungus has first attacked the tap root, it often advances up the centre of the stem and causes a "heart rot," *i.e.* it affects the central heartwood more rapidly than the

outer younger sapwood. A more or less conical decayed region extends up the centre of the stem, sometimes for a length of a couple of feet, the boundary being discoloured and evidently diseased, but still solid, while the inner parts are converted into a honeycomb structure with brown walls, with white fragments of the decayed wood in the cells. If such a stem is cut across above the evidently diseased part, a white covering of mycelium usually appears in the centre of the section within a few days.

A curious variant of the foregoing was recorded in one case. The tree had apparently had what is known as a "heart shake," *i.e.* the wood had split near the centre of the tree along the line of an annual ring. When the fungus grew up the stem it filled the crack with a thick felt of brown mycelium to a height of about three feet.

As indicated above, this disease is not confined to *Hevea*, but attacks cultivated plants of all kinds, except (as far as is known at present) the short-lived annuals. In Ceylon it has been recorded on Ceara Rubber, *Castilloa elastica*, Cacao, Tea, Dadap (*Erythrina*), Caravonica Cotton, Camphor, *Cinnamomum Cassia*, *Erythroxylon Coca*, *Brunfelsia americana*, *Thespesia populnea*, *Hura crepitans*, *Grevillea robusta*, *Codiaeum variegatum* (Croton), *Brownea grandiceps*, Jak (*Artocarpus integrifolia*).

In the Federated Malay States it has been found to attack *Hevea* and Camphor; Brooks and Sharples state that it is infrequent on the former, and usually attacks trees under two years of age, though Bancroft recorded that it appeared to be fairly common on certain areas. It has been recorded from Samoa on *Hevea*, *Castilloa*, Cacao, Breadfruit and *Albizzia stipulata*, and from Java, on *Hevea* and Coffee. In Southern India it is known to occur on Tea and *Hevea*, and in Northern India on Tea and various shade trees. In West Africa it attacks *Hevea*, Cacao, and *Funtumia*.

On new clearings the fungus spreads to the Rubber from decaying jungle stumps and rotting timber, and this may go on as long as either of these remain. In one case (on Tea) the fungus was found to spread to the Tea from decaying stumps of Na (*Mesua ferrea*), the Ceylon Iron-wood, which were at least fourteen years old. But by far the greater

number of cases which occur in Ceylon are on old Cacao land, after the Cacao has been felled.

Brown Root disease is the only root disease of Cacao known in Ceylon. Comparatively few Cacao trees are killed by it, but the fungus develops freely on the Cacao stumps whenever the Cacao is cut down. In 1905 this occurred on several estates on which alternate lines of Cacao had been cut out to make room for Rubber, and in some cases it proved difficult to eradicate, owing to the large number of Cacao stumps, each of which was a potential centre of disease. When writing on this disease in 1911, it was pointed out that where *Hevea* and Cacao had been interplanted it would ultimately become necessary to remove the Cacao ; and when that step had been decided upon the Cacao should be uprooted, not merely cut down, if attacks of Brown Root disease were to be avoided. Recent events have amply justified that statement. On several estates where the Cacao has been removed during the last five years, by merely felling the trees and leaving the stumps, Brown Root disease has been rampant, upwards of ten per cent of the trees having been attacked. In such cases the cost of treating the disease has been much greater than the cost of removing the Cacao stumps originally would have been.

Another instance of the association of Brown Root disease with the stumps of cultivated trees recently came to light in Ceylon. On one group of estates, the boundaries and roads were planted up with the white cotton, or Kapok, tree, *Eriodendron anfractuosum*. Naturally, with such a large and rapidly-growing tree, it soon became evident that they had to be taken out, and when that was done they were simply felled, and the stumps allowed to remain. In the course of a year or two, numbers of these stumps became centres of Brown Root disease, which spread to and killed the adjacent Rubber.

Brown Root disease has also been found to spread to Rubber from a felled *Hevea* log which had been accidentally buried during the construction of a road.

In the most general case Brown Root disease spreads from one tree to another, or from a dead stump to a neighbouring tree, only when the roots of the two are in contact. Instances of this may be quite commonly seen where the

disease has originated on Cacao stumps. But it may be worth while putting on record two cases which give some evidence that it might be possible for the mycelium to spread through the soil, at least for a short distance. In one case a Rubber stump attacked by this disease was planted in a flower pot at the laboratory, and, in course of time, the mycelium extended from the stump to the wall of the pot on one side, binding together the particles of soil in a mass about two inches thick. But it did not pass through the wall of the pot, as the mycelium of *Poria hypobrunnea* will do under similar conditions. In the other case the mycelium spread along dead leaves, etc., at the collar of a diseased *Brownea grandiceps* for a distance of about four inches all round. When this case was found, the mycelium had lost its hyphal character and had formed, on the under side of the dead leaves, a black film covered with a brown powdery layer. This powdery layer can frequently be observed overlying the black crust on diseased roots; it consists of a number of minute spore-like bodies, which, however, do not appear to be true spores.

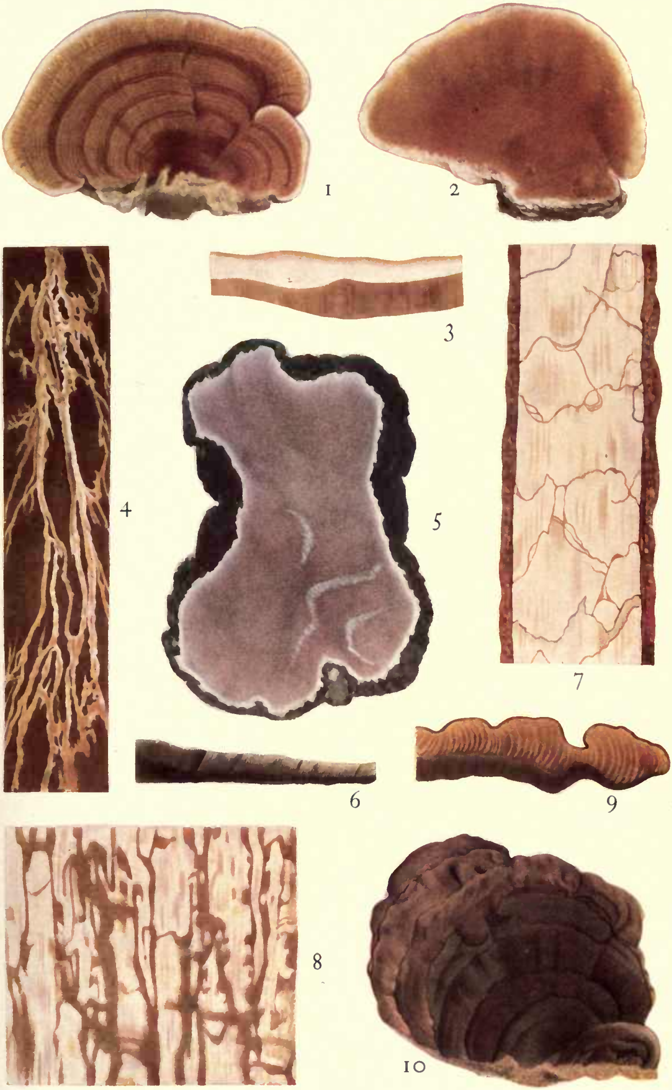
Though, as already stated, this disease is often associated with decaying stumps and timber, there are very many cases, in Rubber, or Tea, or on ornamental trees in Botanic Gardens, in which no stump or decaying timber can be found anywhere in the immediate neighbourhood. In such cases it is obvious that infection must take place by means of spores conveyed to the plant by wind or other agency. But here we were until quite recently faced with the difficulty that no one had been able to find the spores of the fungus, or, indeed, had met with the fructification of the fungus in other than a rudimentary condition. As a rule, a dead tree is found and dug up before the fructification has developed, and the treatment which will cause the production of the fructification of, say, *Fomes lignosus* in the laboratory from diseased roots is usually unsuccessful in the case of Brown Root disease. Even when dead trees have been left standing for some years, until they have finally disappeared owing to the attacks of white ants, no fructification has been formed.

On young Rubber, or other small trees which have been killed by this disease, the fungus sometimes ascends the stem externally above the collar, and there forms a tawny or dark brown crust, free of earth and stones. In Ceylon these

patches are usually small, not more than an inch or two in diameter, but in some countries they are said to cover the stem all round for a length of several inches. Bancroft stated that the only fructification he obtained in Malaya was a badly-developed specimen on Camphor, but that he had seen specimens on Cacao from West Africa in which the brown crust ringed the stem at the collar for a distance of about three inches. These brown patches are minutely velvety, being covered with very small projecting bristles or setae. Such structures are characteristic of the genus *Hymenochaete*, the species of which form, as a rule, flat, encrusting, brown plates, velvety with the bristles in question. Hence it has been customary to consider that the fungus of Brown Root disease is a *Hymenochaete*, and to adopt for it the name *Hymenochaete noxia*, which is that given by Berkeley to the fungus on Bread-fruit in Samoa.

But during the last few years, more particularly during 1917, perfect fructifications have been found in Ceylon on several occasions, on jungle stumps, on Tea and *Hevea* killed by Brown Root disease, and on rotting *Hevea* logs. These show that the fungus is really a *Fomes*, and that the brown patches hitherto observed, the supposed *Hymenochaete*, are merely abortive attempts to produce the *Fomes* sporophore. This *Fomes* is figured on Plate II., Fig. 10. It is bracket-shaped, often irregular and consisting of several brackets fused together. The separate brackets are three or four inches broad, and about one-third of an inch thick, and very hard. The upper surface is purple-brown, usually concentrically grooved, and glabrous. The lower surface is dark brown, or almost black when moist. When broken in two it is seen to consist of a hard, dark, outer crust, with lighter brown tissue internally. The specimen figured (Plate II., Fig. 9) is a lighter brown than usual. The internal tissue usually shows a concentric zoning, with curved transverse lines parallel to the margin. The pores or tubes on the under surface are lined with setae, similar to those which occur on the supposed *Hymenochaete* patches. The fructification is peculiar in that its internal tissues are built up of two kinds of hyphae, the one thin-walled, like fungus hyphae in general, the other thick-walled and resembling the setae in structure. The name of this species is *Fomes lamaoensis*. It frequently

PLATE II.



ROOT DISEASES

occurs in resupinate form, *i.e.* lying flat on the root or stem.

The discovery of the *Fomes* fructification clears up the difficulty of accounting for the distribution of the disease. It is now evident that infection can be conveyed by wind-borne spores from the fructifications on decaying stumps or timber in the jungle or elsewhere. But in Ceylon the fructification is by no means common, and it would seem that special climatic conditions are required for its development.

In illustration of the rate at which the disease spreads the following instance may be cited. *Hevea* was planted, 14 feet apart, in a single line round the boundary of an old-established Cacao estate. When the trees were eight years old one of them died, from Brown Root disease as was subsequently discovered. The tree was left standing and allowed to decay. Two years later the next tree in the line died and was likewise left to decay. After a further period of two years had elapsed, the next tree in the same direction along the line failed to recover after wintering and was evidently dying; and an examination of this tree and the two old decaying stumps proved that they had all been killed by Brown Root disease. Some of the neighbouring Cacao was also killed during the four years, but the path of the fungus from one *Hevea* to the next had been along the rubber roots.

Anstead has recorded an experiment in which a diseased root was buried in contact with the roots of a healthy tree, with the result that the latter was infected and died.

Dead trees should be dug up, with as much of the roots as possible, and burnt. Any neighbouring stump should be similarly treated. The affected spot should be dug over, all dead wood collected and burnt, and lime forked in. In general, practically all the fungus is removed with the dead tree, and in many cases trenching has been dispensed with. But owing to the uncertainty of removing all lateral roots, it is better to err on the safe side, and to trench round the affected area.

When extensive attacks of Brown Root disease occur on old Cacao land, the decaying Cacao stumps must be dug up and burnt. This will generally entail forking over the whole area. It should then receive a dressing of lime at the rate of

at least a ton an acre, in addition to the application of the usual quantity, sixty pounds, to the site of each dead tree. In such cases it is usually possible to detect many trees in an early stage of the disease by noting the occurrence of patches of decayed bark at the collar where a diseased lateral joins the tap root. These cases should be treated by removing the decayed lateral root and all diseased wood and bark at the base of the stem. The cavity should then be tarred, and it would be advisable to fill it up with cement or concrete.

The experiment of immediately replanting a tree of the same species in the place where one had just been killed by this disease was tried at Peradeniya several years ago, and the "supply" has remained healthy. It would therefore appear probable that vacancies might be filled as soon as all dead wood has been removed and the ground limed. But it would perhaps be safer to wait for about six months.

Wet Rot

(*Fomes pseudo-ferreus*, Wakefield)

This root disease has been recorded only from Malaya. It was at first attributed to *Poria hypolateritia*, a common root-disease fungus of Tea in Ceylon, but further fructifications of the fungus have since been obtained, and these have been found to be an undescribed species, which has been named *Fomes pseudo-ferreus* by Miss Wakefield.

The chief characteristic of the disease is the wet rot of the roots attacked. This may vary from a slight dampness only detected on splitting the root, in the case of roots recently attacked, to the complete disorganisation of the tissues into a jelly-like mass.

The external appearance of the diseased roots does not offer any good diagnostic characters. The roots are sometimes slightly encrusted with sand, but not to such an extent as in Brown Root disease, and the crust lacks the small masses of brown mycelium which characterise the latter disease. They resemble to some extent old cases of *Poria hypobrunnea*, and this resemblance is increased by the occurrence in some instances of a dark red superficial mycelium. The exterior of a diseased root is sometimes covered with a very dark reddish skin, which is tough and can readily be

detached from the wood when the root is first dug up. The skin consists of mycelium and bark tissues intermingled. Sometimes a very delicate snow-white mycelium is produced in patches on the exterior of the smaller roots, but no free strands have been observed travelling through the soil.

The action of the fungus on the cortex is peculiar. The middle layers of the cortex appear to be especially attacked and disintegrated, with the result that the outer layers of the cortex disappear, or can be easily removed, leaving the decayed root enveloped by a very thin, white, papery layer, which consists of the inner layers of the cortex only. This is especially noticeable on roots two or three inches in diameter.

The diseased wood may be permeated by brown lines, or plates, of fungus tissue, or broad bands of some substance akin to wound gum, and it may be honeycombed ; but these features are commoner when hardwood jungle stumps are attacked than in the case of *Hevea*. In many cases the wood does not show any coloured bands or plates at any stage of decay.

In advanced stages of decay the wood may become a spongy mass in which its original fibrous character is entirely lost. Pieces of root which have undergone this change may be enclosed in the thin white layer noted above, which forms a continuous outer coat readily distinguished from a wood surface by the presence of the transverse scars of the lenticels of the root and the scars of the smaller rootlets.

The fungus has been found on both hard- and soft-wood stumps, including many of the largest stumps which are often left on estates where the smaller stumps have been removed.

Perfectly-developed fructifications of the fungus are rare, and the present description of it may require modification when further specimens are available. Imperfect fructifications occur as small patches on the under surface of exposed roots. In the most fully developed form hitherto observed the fungus forms a small bracket, hoof-shaped or flattened, white at first, becoming dark brown with a white margin. The upper surface is smooth and hard, and cracks in drying. In section the upper part is woolly, and varies in colour from cinnamon to brown, and the lower part, which consists of the usual *Fomes* layer of parallel tubes, is of the same colour. The lower surface is whitish, and becomes yellow when bruised.

The disease has been found throughout Malaya, but it has not yet been recorded from other countries.

Up to the present no spores have been found in the fructifications seen. Infection of the Rubber trees takes place by contact of the lateral roots with the diseased roots of jungle stumps, or of Rubber trees already attacked. The disease progresses very slowly in living tissue, and it is possible for many trees to be infected, through their laterals, before the first infected tree is seen to be diseased. The fungus seldom rings a tree, but goes up to the collar on one side only. It is said to prefer heartwood to sapwood, and to travel up the centre of a root, leaving the outer tissues untouched.

It has been recorded that, on an estate in Malaya, thirty per cent of the trees in one field were affected before the presence of the disease was suspected. The disease is usually discovered earlier on wet lands, as the roots are poorly developed in such situations, and the trees blow over sooner when attacked.

According to Belgrave, trees are rarely killed by this disease before their eighth year, and the average time for the discovery of the disease on plantations is ten to twelve years. Trees which have been planted very close to jungle stumps may be killed in five years.

Until further details of this disease are known, treatment should follow the usual lines for root diseases in general.

Red Root Disease

(*Poria hypobrunnea*, Petch)

This disease was first seen in Ceylon in 1905. Only one tree, about two years old, was attacked, and as no further cases were observed for many years it was considered probable that the fungus found in that particular instance was merely saprophytic. In 1914 it occurred rather commonly on *Hevea* and *Tephrosia candida* in a new clearing on the Experiment Station at Peradeniya, and since then it has been recorded from several estates in the low country. Up to the present it is by no means a common root disease of *Hevea* in Ceylon, and ranks, in point of frequency, rather with *Sphaerostilbe repens* than with any of the other root diseases. It has also

been recorded from Java, but the *Hevea* root disease assigned to *Poria* in the Federated Malay States is now known to be different.

The appearance of the diseased roots is very variable, and, in consequence, its diagnosis is in many cases somewhat difficult. On young trees, up to about two years old, its identification is fairly easy. The tap root then usually bears external mycelium in a more or less young stage, and in that condition it is unmistakable. The mycelium forms stout red strands on the exterior of the root, which sometimes unite into a continuous red sheet (Plate V., Fig. 4). The strands are smooth and tough on the outside, not woolly, and vary in colour from a bright red to brownish-red, according to age. Internally they are white, so that, if they have been damaged in digging up the root, they appear red and white. When old the strands turn black, and one might pass over the case as one of *Ustulina* in which the fungus had abnormally produced external mycelium. Again, some stones may adhere to the strands, and give the impression that one has to deal with a case of Brown Root disease. But the root is never so encrusted as in Brown Root disease, and there is no brown mycelium between the stones, while it lacks the fans between the wood and the bark which are characteristic of *Ustulina*. In most cases on young trees it is possible to find the red mycelium: if it has turned black on the lower part of the root some red pieces can usually be found at the collar.

The appearance of the diseased wood is also typical in the case of young trees (Plate V., Fig. 3). It is somewhat soft and friable, and is permeated with red sheets. These sheets often run in cylinders in the wood, along the lines of the annual rings, so that they divide the wood into layers, which separate easily from one another and have a red surface.

On older trees the indications are by no means so clear. All the mycelium may then be black, though it is often possible in such cases to find red patches or strands on a lateral which has been more recently attacked. Exposed wood surfaces are usually coloured red-brown. The roots which have been longest diseased are generally soft and wet, and on these there may be a network of narrow white threads between the bark and the wood. The coloured sheets in the wood turn brown when old, or may even become black. I have, how-

ever, seen the typical red sheets in a twenty-year-old *Hevea* where a diseased lateral joined the stem.

The fructification may sometimes be found at the collar of a diseased tree, or along the under side of exposed lateral roots. It belongs to the same group as *Fomes*, *i.e.* it is a Polyporoid fungus, though it does not produce a bracket, but forms a flat plate closely applied to the surface of the root or stem. At first it is yellowish-white, or ochraceous ; it then changes to reddish-brown, and finally to a dark slate colour (Plate II., Fig. 5). In section it is blackish-brown, with a reddish tinge in the intermediate stage (Plate II., Fig. 6). The upper part consists of a layer of tubes, while the lower part is somewhat loose and woolly, though it varies considerably in texture. Its thickness is usually about one and a half millimetres, and it may spread over an area of several inches.

In its occurrence on the Experiment Station, Peradeniya, there is no doubt that it spread to the Rubber from the jungle stumps. Its recent appearance on Rubber estates, about twelve years old, where it was not previously known, is probably to be attributed to the way in which the thinning out was done. It has been found to develop from the stumps of felled *Hevea*, where the trees were cut down at ground level and the stumps left to decay, and it is one of the most regular frequenters of rotting *Hevea* logs. It is always possible to find the fructifications of *Poria hypobrunnea* on *Hevea* logs which have been left to rot, and it is highly probable that to this practice the present attacks of this disease are to be attributed, at least in Ceylon. The fungus is not uncommon on rotting logs in the jungle or elsewhere, and the spores from that source infect the *Hevea* logs lying about the estate. Its simultaneous occurrence on Rubber logs all over an estate is direct evidence of a distribution by means of spores.

On young clearings, and in older Rubber until the stumps are removed, the fungus spreads to the *Hevea* from the lateral roots of the jungle stumps, whether by contact or otherwise. Where felled *Hevea* has been left to rot, it is most probable that it may spread from the logs to the *Hevea* roots by contact, while the fructifications provide spores which can distribute the disease further. It has been found

on lateral roots of *Hevea* two inches in diameter left in the ground after thinning out.

That the mycelium of the fungus can travel from the diseased roots for some little distance, at least, through the soil was demonstrated by the following experiment. A lateral root of *Hevea*, about three inches in diameter, attacked by *Poria hypobrunnea*, was planted upright in the centre of an ordinary twelve-inch flower-pot, and covered with a bell glass. In a few weeks the mycelium had travelled from the root to the side of the pot, had penetrated through the wall of the pot, and was producing a fructification on the outside.

With regard to the rate at which the disease progresses, the following may be noted. *Hevea* was planted on newly-cleared land in June 1913; the trees began to die in 1914: that is quite as rapid as any other root disease. Further, the era of thinning out in Ceylon may be taken as 1913–1916, while the appearance of *Poria* as a root disease on Ceylon estates dates from 1916. Allowing a year for the development of the fungus on *Hevea* logs or stumps, this again indicates a progress equal to that of other root diseases.

The treatment of *Poria hypobrunnea* follows the usual lines. But it is especially necessary that all *Hevea* logs should be removed, as the fungus develops chiefly on them. *Poria hypobrunnea* may be said to prefer logs. It was collected in Ceylon on several occasions before it was known to be the cause of a root disease, and in all cases it occurred on decaying logs, both in virgin jungle at an elevation of 5600 feet and in secondary jungle and scrub at an elevation of 1500 feet.

Besides *Hevea*, this fungus has been found to attack *Hibiscus* (Shoe flower), *Panax*, *Tephrosia candida*, *Crotalaria fulva*, and Tea.

Ustulina zonata, Lév.

This fungus has been known for many years as the cause of the commonest root disease of Tea in Ceylon. It is by no means selective with regard to its host plants, having been found to attack Pumelo, Ebony, *Scolopia*, *Cassia javanica*, *Derris*, Halmilla (*Berrya ammonilla*), Lunumidella

(*Melia dubia*), etc. As the cause of a root disease of *Hevea*, it is common in the Federated Malay States, and fairly frequent in Ceylon. It has also been found to attack *Hevea* in Java and Fiji.

The disease usually attacks old trees, though cases have been seen on trees only two or three years old. On the older trees it is frequently discovered as a "Collar rot" on one side of the stem, *i.e.* the bark is decayed on one side from ground level to a height of one or two feet, often in a more or less triangular patch broadest at the base, and the wood behind the patch is rotten. In Ceylon such cases are usually the result of an attack *via* a lateral root, the fungus having travelled along the lateral to the base of the stem, but in Malaya they can arise at the collar independently of any attack on the laterals, and the fungus attacks the latter later. The decayed bark and wood frequently weathers out, leaving a large hole at the base of the stem on one side. This collar rot and formation of cavities at the base of the stem is not peculiar to *Ustulina*, but occurs also in Brown Root disease.

In other cases the fungus attacks the tap root below the region where the larger laterals arise, and works completely through it. It advances for some distance up the middle of the stem, but, in general, does not descend far down the tap root. It frequently happens that when the upper part of the tap root is quite decayed, the part a foot or so below ground does not show any signs of the fungus. The cortex on the lower part of the root then turns bluish or purple internally, and the root has an offensive smell: specimens in this condition superficially resemble roots killed by *Sphaerostilbe repens*.

When the tap root is destroyed the tree is often blown over before any sign of disease is noticeable in the crown. Similarly, when the tree is attacked on one side at the base, the disease is usually discovered before the crown has begun to suffer. But failing either of these, the fungus gradually travels round the stem and along the laterals, and as the decay of the base and the roots progresses the branches gradually die back.

In Ceylon the progress of the disease on the individual tree appears to be slow. Death of the tree may not occur until a long time after a large hollow has been caused on

one side. Latex is still obtainable on the sound side of the tree, and in several instances an abnormal flow of latex has been reported from trees badly attacked on one side by *Ustulina*. An extreme example of the slow rate of progress of this disease on some trees other than *Hevea* is furnished by a *Eugenia* in the Royal Botanic Gardens, Peradeniya. The base of the stem on one side is severely attacked, and produces successive crops of fructifications in every monsoon. But it is known to have been in this condition for at least ten years, and the only effect observable to the casual observer is the death, now and again, of one of the thinner topmost branches. It is to be noted, however, that if the course of the disease is slow it is in consequence more to be feared, as a large number of trees may be attacked before anything serious is noticed.

Sharples states: "This root disease is common on most of the older plantations in the Federated Malay States, though its presence is unsuspected. The fungus works slowly and insidiously, the crown of leaves becoming thin as it progresses in the collar. The diseased tissue is usually confined to one side of the collar, and from this side latex cannot be obtained. The opposite side may give a good yield, and tapping is continued till the amount of latex obtained begins to diminish. When this stage is reached the tree soon dies and is taken out."

Fig. 4.—*Ustulina zonata*; black lines in wood. × ⅓.

The affected wood at the base of the stem is permeated with conspicuous black lines (Fig. 4). These run irregularly up and down the stem, or transversely. The wood is divided

up by thin sheets of black tissue, and the edges of these sheets appear as lines when cut. Sometimes these sheets form closed pockets, and in section appear as irregular ovals or circles surrounding dark-coloured patches of diseased wood. Between the black lines the wood is sometimes uniformly brown (Fig. 5). Emphasis is laid, in the Federated Malay States, on the fact that the diseased wood is dry and tindery, "like touchwood," and hence the disease has been named "Dry Root and Collar Rot."

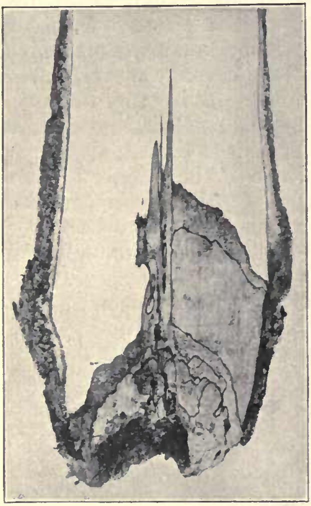


FIG. 5.—*Ustulina zonata*; black lines and brown areas in wood. × ⅓.

Typical characteristics of the disease on the roots are best seen by examining the laterals. There is no external mycelium, such as is found in *Fomes lignosus* or Brown Root disease. The roots (Fig. 6) frequently bear small black nodules, two or three millimetres in diameter, which are white internally and may appear white on the top if they have been damaged when the root was dug up. They are usually scattered, and not in large numbers. They are formed by the emergence of the mycelium from the diseased tissues, and, had the root been exposed, would no doubt have developed into fructifications. In advanced cases there is frequently a continuous, thin, black layer or crust beneath the outer papery layer of the root. Between the bark and the wood there is generally a thin film of white or brownish mycelium, arranged in fans (Fig. 7), frequently with black lines bordering the outer ends of the fans. This last is the most characteristic feature of roots attacked by *Ustulina*, whether Rubber or Tea. As in the stem, irregular black lines are usually present in the wood of the root.

It may be noted that although black lines occur abundantly

in wood attacked by *Ustulina* they are not invariably an

FIG. 6.—Root attacked by *Ustulina zonata*, showing external black cushions. × ½.

indication of this disease. Many other fungi which belong

FIG. 7.—*Ustulina zonata*; mycelium between the wood and the bark. × ½.

to the same class as *Ustulina* form black lines in wood, and the majority of them are merely saprophytic.

The fructification of the fungus (Fig. 8) is usually produced in profusion at the base of the stem, generally before the tree is dead. The fungus emerges through the bark as a short, white column, one or two millimetres in diameter, and spreads out in all directions flat on the surface of the bark, being attached to the bark only at the point of origin. It thus forms a flat plate about four or five centimetres in diameter, but several may arise side by side and fuse into a continuous plate covering a large area of the

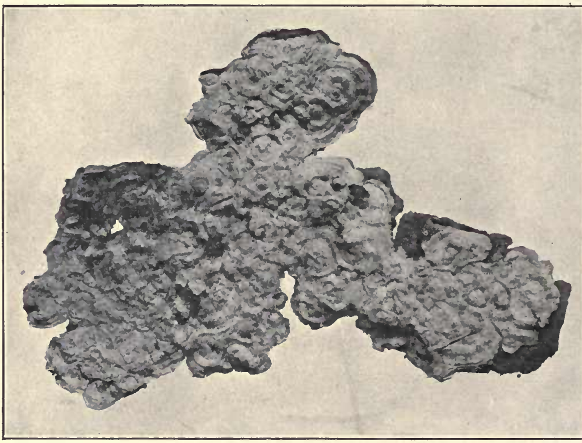


FIG. 8.—*Ustulina zonata*; fructification. × ½.

base of the stem. These plates are at first white and soft, but soon become grey or greenish-grey. In the typical form they are generally concentrically zoned or corrugated. They then harden and become purple-grey, and finally weather to black; in these later stages they bear scattered, minute, black, slightly elevated points. After the plates have become hard they are at first white internally, with a single layer of dark, oval, or globose cavities (Fig. 9); later they become black internally, and more or less hollow. When old they are brittle, and easily crumble to pieces when handled. They are usually not more than about two millimetres thick.

Though the fructification is, in general, more or less flat when it grows on the bark of *Hevea*, it may assume other forms, especially if growing on an irregular surface. At the base of the tree it often grows over irregular bark, or even over soil, etc., and is then thrown into irregular undulations, and may lack the concentric zoning. Its crusty, brittle texture is a good distinguishing character. It differs from most of the other black, brittle, encrusting fungi which are encountered on a Rubber estate, in that it is only attached to the substratum at one point, or when several fructifications have fused together, at a few scattered points. Consequently it can readily be detached whole from the bark. On the other hand, most of the other fungi which form black crusts are attached over their whole under-surface and cannot be lifted off.

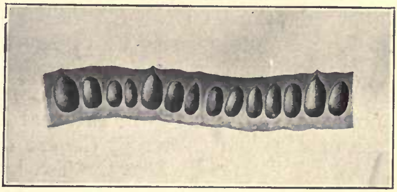


FIG. 9.—*Ustulina zonata*; section of fructification. ×6.

Ustulina zonata produces two kinds of spores. The first appear when the plate is in the white stage, and are borne on erect stalks closely packed together over the whole surface. These are consequently borne superficially and can easily be blown about by the wind. The second kind of spore is produced in the oval cavities already described, and, when ripe, is extruded in minute black masses through the mouths of the cavities, which are the black points on the surface of the mature plate.

Brooks in 1916 suggested that, in Malaya, the fungus began to grow on decayed stumps and spread from one tree to another by contact of diseased roots with healthy ones. But he pointed out that on some of the older estates on which the disease had been found, very few stumps remain, and that it is therefore likely that there are other means of infection. He stated that some of the trees attacked by *Ustulina* had previously been attacked by white ants, and thought it might be probable that this disease might frequently follow an attack of those insects. In the same

year Sharples stated that the fructifications had been found on jungle stumps left after burning.

The prevalence of *Ustulina zonata* as a root disease of Tea is due to the practice of growing Grevilleas through the Tea, and felling them when they have grown too large. The fungus develops on the *Grevillea* stump and travels down its lateral roots, passing on to any Tea root which happens to be in contact with the Grevillea roots. To a lesser extent the same happens when *Albizzia moluccana* is felled, but another root disease is more usual in that case. The first case of *Ustulina* as a root disease of *Hevea* in Ceylon was in an old Tea field where the Tea had been abandoned and allowed to die out. In that case the *Ustulina* undoubtedly spread from the dead Tea roots to the *Hevea*. In another case *Albizzia* and Lunumidella had been planted as shade trees along the roadsides of a Tea estate, and the Tea was subsequently interplanted with *Hevea*; after some years the shade trees were cut out, and in numerous instances the course of their lateral roots was marked by a line of dead Tea bushes and one or two *Hevea*, either dead or attacked by *Ustulina*. On another estate *Albizzia* had been planted at the same time as the *Hevea*, and cut out later; many *Hevea* trees were subsequently attacked by *Ustulina*, and clear cases of infection on the tap root just below the laterals were demonstrable, where a dead lateral root of the *Albizzia* was in contact with a *Hevea*. *Ustulina* has also been found to develop on Cacao stumps where Cacao interplanted among Rubber has been cut out, and on *Hevea* stumps left after thinning out.

The prevalence of *Ustulina* root disease in Ceylon during the last five years must, to a considerable extent, be attributed to the practice, which was common in the early days of thinning out, of leaving the felled *Hevea* logs to rot among the standing Rubber. *Ustulina zonata* is one of the commonest fungi on rotting *Hevea* logs in Ceylon, especially when they are six to twelve months old. The numerous fructifications produce countless numbers of spores which can infect the *Hevea*, and it is possible that the fungus may pass from a decaying *Hevea* log to a living root on which the log may happen to rest.

As noted in the Federated Malay States, cases of *Ustulina*

root disease occur on Rubber in fields where old stumps have disappeared, or have been removed, and all felled timber cleared up. There is seldom any way of estimating how long a tree has been attacked, and, as the disease is usually a slow one, some of these infections may date from the time when stumps or timber were present. But there is no reason to doubt that *Ustulina zonata* will be able to attack *Hevea* of any age, more especially through wounds, by means of wind- or insect-borne spores, independently of the presence of any jungle or *Hevea* stumps or rotting logs. That spore infection does happen is evident from the attacks of *Ustulina* on the stem, several feet above ground, without any occurrence of disease in the roots.

The treatment of cases of root disease caused by *Ustulina zonata* should follow the usual rules for root diseases in general. Dead trees and any neighbouring dead stumps, whether jungle stumps or old *Hevea* stumps left after thinning out, should be dug up and burnt. Care should be taken to follow up and extract the laterals as far as possible, as the disease spreads from tree to tree by contact of diseased roots with healthy ones of neighbouring trees. The fungus has not been found to produce free strands of mycelium in the soil, but, nevertheless, it is best to trench round the affected area and so sever the roots of surrounding trees which run into the latter. The cut ends of healthy roots on the outer wall of the trench should be tarred. Lime should be forked in over the enclosed patch.

When the disease is discovered as a collar rot there is generally a desire to retain the tree until it dies, as it usually yields latex in normal quantity, or more than normal quantity, on the unaffected side, and above the diseased area. In that case any diseased lateral root and any neighbouring stump should be dug up and burnt, the diseased wood and bark at the base of the stem cut away, and the wound tarred. Modern methods of tree surgery might be applied in such cases, and the hole filled up with cement concrete or brickwork to give support to the stem. Such measures have not yet been extensively tried in the tropics, and it is doubtful how far they can be employed, and whether the tree will survive long enough to make the operation profitable. But if the tree is not to be treated it should be removed. Leaving a diseased

tree untreated until it dies is to be deprecated, as it will bear fructifications which will produce innumerable spores and possibly infect others. The periodic collection of fructifications is impracticable in the case of *Ustulina*, which forms its fructification rapidly and bears spores in its early stages.

The removal of felled *Hevea* is now general, and it is no longer necessary to emphasise the necessity of getting rid of that source of *Ustulina* and other parasitic fungi.

Sphaerostilbe repens, B. and Br.

This root disease was first discovered in Ceylon in 1907. Since then it has been found in that country on several occasions, but in no case has it caused any widespread damage. It has also been reported from Malaya, where it is said to be by no means rare on old Rubber.

In the first case observed, it killed three large trees about twenty-five years old. These stood in a patch of undrained sour soil, between a set of cooly lines and a factory, where their surface roots were constantly being damaged. This area was used as a storage ground for firewood, and it is most probable that the fungus was brought with the dead wood and attacked the damaged lateral roots. In another case a single tree about twelve years old, which stood in swampy ground at the side of a stream, was killed. In each of two other instances, an old tree, again in swampy soil, succumbed to its attack. Judging from these cases, the disease would appear to be most frequent in swampy or sour soil, but in another instance it killed young trees, about two years old, in average plantation soil, and several further cases have been noted under similar conditions.

The records show that in Ceylon it is not confined to any particular district. As is natural, seeing that rubber is chiefly a low-country product, most of the cases come from the low country. This, however, does not indicate that they are from swampy areas, as, in Ceylon, low-country Rubber is principally on hilly or undulating land. But cases also occur up to 2000 feet, about the maximum elevation at which Rubber is grown in Ceylon, and the fungus has been found as a saprophyte in various districts up to that elevation.

In Malaya the disease was recorded by Richards in 1913;

and in 1914 Brooks found that a considerable number of trees were affected by it. According to Brooks the disease is by no means rare in old Rubber planted on low-lying land in Malaya, having been found in Northern Perak, in the district round Teluk Anson, and in the coast lands of Selangor. Only a few trees on undulating land were seen to be attacked by it.

The mycelium of the fungus at once distinguishes this disease from those caused by *Fomes lignosus* and *Fomes lamaoensis*, but it is not immediately evident like that of the two latter species. When the root is dug up the cortex is found to be decayed, but there is no external mycelium. But if the cortex is removed, black or red flattened strands are seen running over the surface of the wood (Fig. 10). The inside of the cortex and the outer layers of the wood are usually a deep blue, or purple, when fresh, and have a particularly foul smell. The blue colour, however, is not confined to roots attacked by this disease, but sometimes occurs on tap roots killed by *Ustulina*, below the level at which the *Ustulina* has attacked them. The smell, too, is not a distinctive sign of this disease,

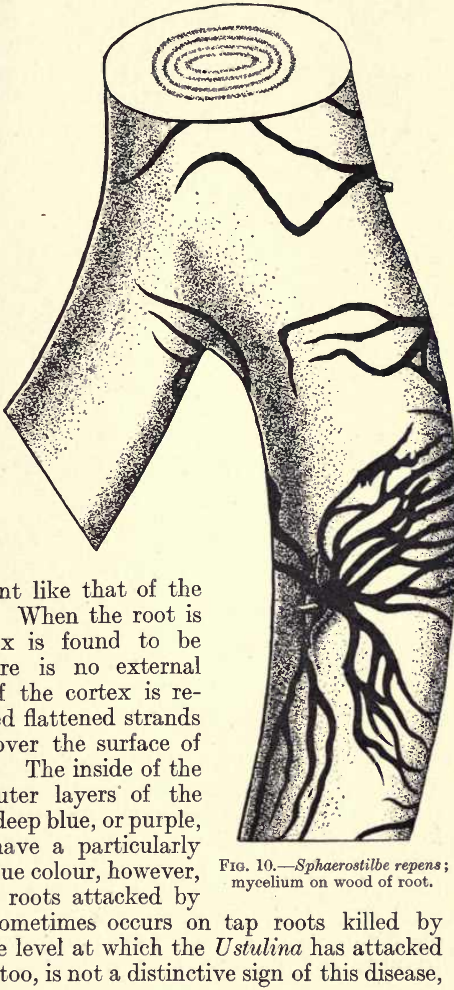


FIG. 10.—*Sphaerostilbe repens*; mycelium on wood of root.

and is probably caused, not by the *Sphaerostilbe*, but by the action of secondary organisms on the cortex or wood.

The mycelial strands are usually about two millimetres broad, but they may reach a breadth of five millimetres. At first they are red externally and white internally, but when the root is much decayed the strands decay also and become black. If the fungus is living the strands are fairly thick and stand out prominently above the wood, but on old decayed roots they are little more than a black film on its surface. When the cortex is stripped off the wood the strands are often split lengthwise, especially when they are in a living condition, and half remains on the cortex and half on the wood. The white inner tissues of the fungus are then exposed, and these often present a fern-like arrangement. These strands are not simple cords composed of hyphae lying side by side, such as occur in *Fomes lignosus*, but have a definite cortex, different in structure from the inner tissue. They constitute what are known as rhizomorphs.

Figure 10 indicates one way in which the fungus may attack a tree. The mycelium enters the smaller roots and advances along them until it reaches the larger. There its rhizomorphs spread out and branch, and these branches run between the cortex and the wood until the tap root is reached. On the tap root it forms similar strands, but at the collar it may form a continuous red sheet, between the wood and the cortex as before. The point on the figure from which the strands radiate is the place where a small root, about two millimetres in diameter, joined the larger root. Sometimes the strands run in the cortex, beneath the thin papery layer which forms the external covering of a *Hevea* root and which can usually be peeled off when the root is dead.

The decay of the root is brought about by fine hyphae which are given off by the rhizomorphs and permeate the wood and cortex. The fungus may ascend from the collar for some distance, two or three feet, up the stem, and the rhizomorphs may occur there either in the bark or between the bark and the wood.

A stronger development of mycelium is shown in No. 7 on Figure 11. In that case the rhizomorphs are much broader, and they have fused behind into a continuous

sheet. The outer surface of the rhizomorphs is marked with a peculiar herring-bone pattern; this occurs also on the narrower rhizomorphs which are usually found in *Hevea*, but it is not so easily recognised there. This particular specimen was found between the wood and the bark of a decaying Dadap log (*Erythrina lithosperma*). When the bark was separated from the wood these thick strands were often split horizontally, and the white internal tissue then presented a fern-like appearance. The patch of mycelium was over a yard in length and about eight inches broad, the separate rhizomorphs being evident only at the margin.

The fructifications of the fungus are produced on the diseased tissues, or on the rhizomorphs when the latter have become exposed through the cracking or weathering off of the bark. The first form of fructification has been observed by Brooks on clayey soil lying in contact with diseased roots. The fructifications are of two kinds,—a conidial form, in which the spores are borne free at the apex of short stems, and a perithecial form, in which the spores are enclosed in perithecia.

The conidial fructifications are the first to appear. They take the form of short, erect, red stalks from two to eight millimetres high, and half to one millimetre in diameter, surmounted by a white or pinkish globose head, one to one and a half millimetres in diameter. Though individually small, they occur in large numbers and are consequently fairly conspicuous. The stalk is hairy at first, but becomes glabrous in the lower half later (Fig. 11).

There are two common conidial fructifications often found on *Hevea* which might at first sight be mistaken for that of *Sphaerostilbe repens*. One of these, *Stilbum nanum*, Massee, is frequently found on *Hevea* twigs. The other, *Stilbum cinnabarinum*, Mont., often occurs in large numbers on dead *Hevea* bark, sometimes accompanied by minute red spheres, which are its perithecial stage, *Megalonectria pseudotrichia*, Schw. Both these have red stalks and red or pinkish heads, like minute pins, but their stalks are smooth, not hairy, and they can easily be distinguished with a hand lens from the conidial stage of *Sphaerostilbe repens*.

The second or perithecial stage of the fungus follows the first stage on the same area, but in many cases it does not

appear to be produced. The perithecia are small dark red bodies, rounded below and conical above, about 0·6 mm. high and 0·4 mm. in diameter (Fig. 11). They are crowded together on the bark, at the edge of the mycelium if that is exposed, or round the bases of the old stalks, or even along the stalks. They are identical in structure and appearance with those of a *Nectria*, but as the conidial stage differs from that of a *Nectria*, the fungus is placed in a different genus.

Sometimes the rhizomorphs of *Sphaerostilbe repens* become superficial, *i.e.* run along the surface of the host plant, especially when the fungus is only saprophytic; the conidiophores and perithecia are then borne anywhere along them.

Sphaerostilbe repens was first collected by Thwaites at Peradeniya about the year 1868. His specimens grew on Jak (*Artocarpus integrifolia*). Whether it was parasitic or saprophytic is not recorded, but judging from later occurrences it was probably only saprophytic. In 1908 a healthy Jak tree in the Botanic Gardens was felled, and soon afterwards *Sphaerostilbe repens* developed in abundance on the chips which were left lying round the base of the stump.

It was found in 1906 on a decaying Dadap log about a foot in diameter. The tree was quite sound when felled, so that the fungus in this case also was only saprophytic.

Specimens were sent in in 1906 on the rhizome of arrowroot (*Maranta arundinacea*). In this case it was undoubtedly parasitic. The rhizomorphs had apparently spread through the soil to the arrowroot, and, after growing for some distance along the scale leaves, had penetrated into the rhizome, where they formed a number of more or less parallel strands running lengthwise through it. The rhizome was decayed along one side, but in general the tissue surrounding the rhizomorphs appeared quite sound. The extension of the rhizomorphs would appear to depend on the supply of food from behind, not on food obtained from the immediately surrounding tissues, at least in the early stages of extension.

This fungus has also been found to attack the roots of the Papaw. In advanced stages the soft tissue in the centre of the stem is, at the base, converted into a pulpy rotting mass, and the rhizomorphs form a wide-meshed network which can be extracted in large sections.

Conidia (*i.e.* the first kind of spore) sown on cut surfaces of arrowroot developed the first stage of the fungus in seven days and the perithecial stage in twenty-one days.

Brooks, in Malaya, attempted infection experiments with *Sphaerostilbe repens* on *Hevea*. Roots of seedling *Hevea* in pots, and of four-year-old trees on hilly land, were inoculated with material of the fungus from pure cultures. A block of *Hevea* wood on which the mycelium was growing, or mycelium from an agar culture, was placed against a root, which in some cases was wounded and in others not injured. Sixteen plants were treated, but after nearly five months none of them showed signs of infection. Brooks considers that this negative result points to the possibility that some condition which disposes to susceptibility must exist before the fungus can invade the roots of a Rubber tree, and points out that bad aeration of the soil, consequent on deficient drainage, may be a factor in inducing the requisite condition for the fungus to enter.

As previously stated, the fungus develops freely on small pieces of Jak wood, and it has been found to spread to *Hevea* from decaying Jak stumps. In this respect it resembles *Fomes lignosus*, and provides an additional reason for the removal of Jak stumps. It also occurs on felled Dadap logs, and has been found to cause root disease of *Derris robusta*, so that it is probable that it may attack members of the order *Leguminosae* in general. In the first case recorded the fungus was probably introduced with firewood, *i.e.* miscellaneous jungle timber.

Dead trees must be dug up and burnt, as much of the roots as possible being extracted, especially the laterals. Any neighbouring stump should also be dug out, and all pieces of wood collected and burnt. Small pieces of wood are quite sufficient to provide a suitable habitat for the fungus. The affected area should be surrounded by a trench about two feet deep, and the ground dug over and dosed with lime, which should then be forked in.

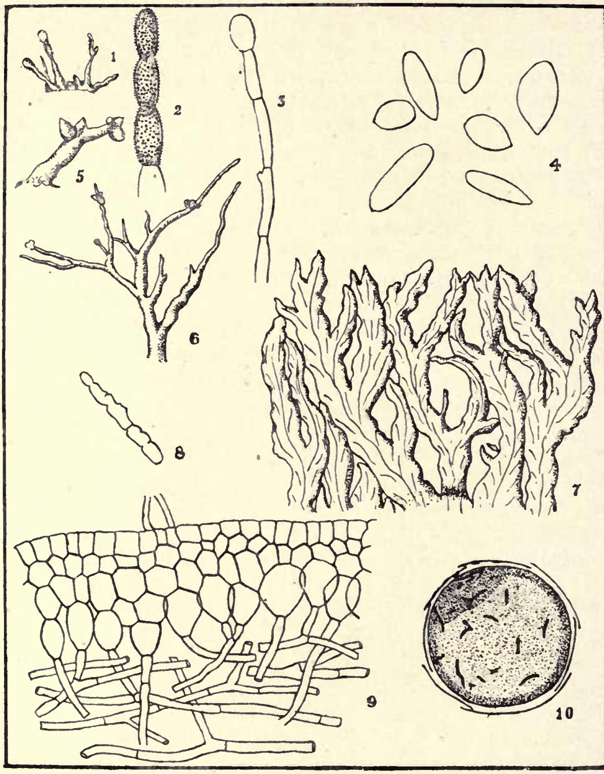


FIG. 11.—*Sphaerostilbe repens*; details of the fungus.

No. 1. A group of conidiophores. × 2.
No. 2. Tip of a hair from the stalk. × 350.
No. 3. Conidiiferous hypha from the apex of the conidiophores. × 500.
No. 4. Conidia. × 600.
No. 5. Perithecia on an old conidiophore. × 6.
No. 6. Groups of perithecia on a horizontal rhizomorph. × 2.
No. 7. Rhizomorphs from dadap.
No. 8. Cross section of a rhizomorph; outline only. × 2.
No. 9. Cross section of the cortex of a rhizomorph, magnified.
No. 10. Cross section through the rhizome of arrowroot attacked by *Sphaerostilbe*; the dark lines are the sections of the rhizomorphs.

Root Disease of "Stumps"

(*Botryodiplodia Theobromae*, Pat.)

In several cases in Ceylon *Hevea* stumps which had been planted out under favourable conditions failed to grow. Generally the plants made no growth whatever, but occasionally some developed a green shoot about six inches long and then died. They were usually sent in as examples of the damage done by white ants, because the tap root, as a rule, had been partly eaten away, all the cortex having disappeared, and only an irregular spindle of wood left. In practically every case it was determined that death was due to *Botryodiplodia Theobromae*, the fungus which causes Die-back.

When the root was split open black streaks were found running longitudinally down the wood. This discoloration is due to the mycelium of the fungus, which is dark-coloured when mature. The cortex was also blackened internally (when present) and contained the characteristic fructifications of the fungus; and in some cases these fructifications formed large black cushions at the points of origin of the small secondary roots after the latter had disappeared.

In these cases the fungus had entered the plant, not at the top as in Die-back, but either below ground or at the collar. It is probable that, in the majority of cases, its entrance was facilitated by injuries inflicted during planting, but in one case at least it would appear that the fungus was able to attack uninjured plants.

In general, further loss was avoided by liming the holes where the plants had died and supplying with basket plants, but in one case some of the supplies died from the same cause. The evidence afforded by other crops appears to show that this fungus can live in the soil, and can attack the roots of uninjured plants; it causes a serious root disease of Tea in Ceylon.

This disease in Ceylon proved worse on Rubber planted among Tea and on old chena land (*i.e.* jungle land previously cleared for temporary native cultivation) than on land which was newly cleared of virgin jungle. The plants attacked were usually about two inches in girth. It was recorded from Ceylon and Burma in 1906, and in one instance in the latter country sixty per cent of the stumps were killed. In 1909

it was recorded from the Federated Malay States, the stumps attacked being about three inches in girth, and eighty per cent being killed.

Polyporus rugulosus, Lév.

This fungus was found by Brooks in Malaya under conditions which appeared to indicate that it was the cause of a root disease, but it has not yet been definitely decided that such is the case. It was observed on several occasions growing at the collar or upon exposed lateral roots of diseased Rubber trees, only on trees which were in tapping, and appeared to be more frequent on badly-drained, low-lying estates than on undulating land. The bark and wood near the fructifications was invariably decayed, the foliage of the affected trees became thin, and the branches died back. One tree which was severely attacked had been previously invaded by white ants.

The fructifications of the fungus are bracket-shaped, thin, and only an inch or two in diameter, but they occur in numbers one above the other, and form large groups several inches across. They are fleshy when young, and become leathery when old. The upper surface is smooth, brownish, and concentrically zoned ; the lower surface is white at first, and becomes yellow-brown when old. It differs from *Fomes lignosus* in its smaller size, the colour of the pore surface, and its thinner substance.

It is advised that trees which are apparently affected by this fungus should be treated as for *Fomes lignosus*.

Wounds on exposed Lateral Roots

Wounds on exposed lateral roots are very common on old Rubber in Ceylon. They are confined to the upper surface of the roots, along which a continuous wound may extend for several feet. It has been suggested that they are caused by stones which are washed down the hill-sides, but that suggestion would seem to be negatived by the fact that for a considerable time the dead cortex remains intact within the wound. Another suggestion is that they are caused by coolies walking over the roots. It has to be borne in mind

that the roots are not developed on the surface, but are brought to that position by their growth in thickness and by the loss of soil through wash, and it is possible that this unnatural exposure may be the primary factor in the causation of these wounds.

The first stage in their formation is the death of the cortex over the upper surface of the root. This occurs in varying lengths, and may extend from side to side of the exposed part, or be confined to a narrow strip down the middle. Growth of the root in thickness is then arrested over this dead area, which is consequently surrounded by a more or less swollen rim or callus. The dead bark persists for some time within the wound, but ultimately cracks and disappears. The wood which is then exposed is black on the surface and brown within, and, in old wounds, this region of discoloured dead wood may extend half-way through the root, being separated from the healthy wood by a red-brown line. The wood is at first quite hard, but after prolonged exposure it breaks up and leaves a hollow in which rain-water collects.

Occasionally these wounds heal up naturally. Generally, however, they gradually spread along the root in both directions, and widen until they reach ground level on either side. In long-standing cases the edges of the wound are often margined by a series of ridges, the successive callus borders which have been killed as the wound broadened. The wounds extend along the root right up to the trunk, but they have not been observed to ascend the stem. It is, however, very probable that the gradual decay of the wood will proceed from the root into the stem without giving any outward indication.

The death of the cortex, which begins the injury, may take place over a large area in a short time, and the extent of this decides the size of the original wound. The subsequent enlargement of the wound takes place very slowly.

Where an exposed lateral root dips below the surface and reappears further on, wounds may be formed on both the exposed parts, but the bark on the buried part of the root is, as a rule, healthy, though the discoloured wood may extend within the root from one wound to the other.

The fungus which is generally present on the dead bark is *Aposphaeria Heveae*. This is common on dead *Hevea*

branches and felled logs, and it is very doubtful whether it is parasitic. It forms black, slightly projecting lines in the cracks of the bark.

Up to the present no effect on the general health of the tree has been observed as a result of these wounds, and estates, as a rule, have not undertaken any treatment of them. It would be advisable to try to prevent further decay by painting them with Brunolinum or Jodelite, and subsequently with coal tar. If the decayed wood is scraped out care should be taken not to leave a hollow in which water can lodge; it may be necessary to cut away part of the healthy tissue on one side of the wound to ensure drainage.

Whether it is advisable to terrace round the trees and cover the wounded roots with earth is an unsettled question. It is possible that under such conditions the growth of callus might be more active, and the wound might heal. On the other hand, there is perhaps a greater probability that the decay of the wood might be accelerated, and that the roots might be attacked by *Ustulina*. If terracing is tried with this end in view the wounds should be tarred and the tar allowed to dry first. In young plantations terracing should be adopted as soon as, or before, the lateral roots are exposed.

It remains to be seen whether the tree can compensate for the loss of these roots by producing others at a lower level.

SUMMARY

ROOT DISEASES

FOMES LIGNOSUS, Klotzsch

Identification.—White, yellowish, or reddish strands on the roots (Fig. 1; Plate II., Fig. 4): young strands feathery (Fig. 2); all firmly attached to the root. Decayed wood soft, often wet. Fructification, a red-brown bracket, concentrically zoned (Plate I., and Plate II., Fig. 1); lower surface orange, then red-brown (Plate II., Fig. 2); when broken the section shows two colours (Plate II., Fig. 3).

Occurrence.—In clearings the fungus starts on decaying jungle stumps, and spreads from them to the roots of the *Hevea*. It similarly starts from *Hevea* stumps left after thinning out, abandoned Tea, Cacao stumps, and stumps and logs of the thorny or smooth Dadap.

Treatment.—See pp. 40, 41.

Brown Root Disease

(*Fomes lamaoensis*, Murr.)

Identification. — Roots encrusted with sand, earth, and small stones, fastened to the root by fine brown mycelium which is collected here and there in brown masses. When old a black crust develops over the brown masses (Fig. 3). Wood permeated, sometimes honeycombed, by brown lines or bands (Plate II., Figs. 7 and 8) with sometimes a few thin black lines. Fructification rarely developed—a very hard, purple-brown bracket (Plate II., Fig. 10), pale or dark brown in section (Plate II., Fig. 9).

Occurrence.—Spreads to Rubber from jungle stumps, *Hevea* stumps, etc., by contact. Very common on old Cacao land where the Cacao has been cut down. Attacks cultivated trees and shrubs of all kinds, but progresses slowly, and does not cause great damage except where Cacao has been cut out of mixed *Hevea* and Cacao.

Treatment.—See pp. 24, 49.

Red Root Disease

(*Poria hypobrunnea*, Petch)

Identification.—Red strands on the exterior of the root (Plate V., Fig. 4); these turn black when old. Red sheets and plates in the decayed wood (Plate V., Fig. 3); these turn brown when old. Fructification, a flat plate, white or ochraceous at first, then red-brown, finally slate coloured (Plate II., Fig. 5); in section blackish-brown (Plate II., Fig. 6).

Occurrence.—In new clearings spreads to *Hevea* from jungle stumps. The red strands can travel free through the soil for a short distance. Common in old Rubber on rotting *Hevea* logs.

Treatment.—See pp. 24, 55. Clearing up all timber is essential.

Wet Rot

(*Fomes pseudo-ferreus*, Wakef.)

Identification.—Diseased roots wet; in advanced cases converted into a jelly-like mass. Sometimes a very dark, reddish skin on the exterior of the root; this can be peeled off when fresh. Brown lines or plates, or broad brown bands, in the wood. Fructification rare.

Occurrence.—Develops on jungle stumps, and passes to *Hevea* roots by contact. Only known to occur in Malaya.

Treatment.—As for root diseases in general. Complete removal of stumps necessary.

Ustulina zonata, Lév.

Identification.—No external mycelium. Decayed roots often dry, and usually permeated with thick black lines (Fig. 4). White or brownish fans of mycelium between the bark and the wood (Fig. 7). Fructification formed at the collar, a flat or undulating plate, at first white, then greenish, then purple-grey, finally black (Fig. 8). When old the fructification is crust-like and brittle. Plates often concentrically zoned.

Occurrence.—Attacks *Hevea* from abandoned Tea, *Hevea* stumps, *Albizzia* stumps, etc., by root contact, and by spore infections on wounds. The fructifications occur abundantly on decaying *Hevea* logs.

Treatment.—See pp. 24, 63. Rotting *Hevea* logs must be cleared up.

Sphaerostilbe repens, B. and Br.

Identification.—Red strands of mycelium between the wood and the bark; these turn black when old (Fig. 10). Root usually bluish-purple and foul-smelling.

Occurrence.—Has been found on rotting Jak (*Artocarpus integrifolia*) and Dadap (*Erythrina lithosperma*) logs. Attacks Papaw, Arrowroot, and Tea. Probably spreads to *Hevea* from decaying timber.

Treatment.—See pp. 73, 74.

Wounds on exposed Lateral Roots

Cause unknown. Scrape out decayed wood; paint with Brunolinum or Jodelite, etc., and then tar (see p. 74).

CHAPTER III

LEAF DISEASES

In 1911 the statement that plantation Rubber was not subject to any serious leaf disease was an accurate summary of the conditions then known to exist. Several diseases were known, but none of them had been found to cause any notable damage. Since that time, however, the situation has changed completely, and among the new leaf diseases which have made their appearance are two which are capable of becoming a serious menace to the rubber industry. One of these is at present confined to South America, where it occurs in all rubber-growing countries, and is reported to have become so virulent in at least one of them that it is doubtful whether *Hevea* can be cultivated at a profit. The other, which occurs in Ceylon and India, and probably in Java also, partly defoliates the trees in wet years, but is so largely dependent upon climatic conditions that, in Ceylon at least, it is not epidemic annually. If, however, a series of consecutive years of heavy rainfall should happen, and this abnormal defoliation occur annually in consequence, the resulting damage would become very serious.

The occurrence of these two diseases should serve to disprove the theory, which has previously been shown to be a fallacy, that because *Hevea* sheds its leaves annually it is less liable to be attacked by leaf disease or will suffer less damage when attacked than Tea, Cacao, or Coffee, which are evergreen. In many cases, and the South American leaf disease is a case in point, the fungi which attack the leaves of deciduous trees pass through two (or more) different stages in their life-history. In the first stage they produce spores which serve to convey the disease immediately to other leaves, while in another stage they produce different spores more

resistant to drying or to climatic influences. This second stage is often passed in the dead fallen leaf, and its spores carry the fungus over the period when the tree is leafless. Thus the actual defoliation does not necessarily involve the destruction of the fungus; and, in actual fact, the serious leaf diseases of deciduous trees are more numerous than those of evergreen trees. The South American leaf disease also brings into prominence another phase of the life-history of the *Hevea* tree, which renders it more liable to the continued attack of a leaf disease, viz. that as all the trees do not "winter" at the same time, there are always some in leaf, and capable of transmitting any disease to the new foliage of the others. And there is the further point that the leafless phase is of such short duration that many spores of the first stage of a fungus might survive it.

There is general agreement among mycologists, who have had actual experience of Rubber estates, that the method usually adopted for the control of leaf diseases, viz. spraying with a fungicide, is impossible in the case of tappable *Hevea*. The various methods which have been proposed for combating the more serious leaf diseases of *Hevea* are quoted under the special diseases concerned.

The South American Leaf Disease

(*Fusicladium macrosporum*, Kuyper)

The most serious leaf disease of *Hevea* which has yet been recorded is at present confined to South America. It was first discovered in the Amazon Valley, but has since made its appearance in Trinidad and British Guiana, and has done great damage in Surinam.

The disease appears first on the young leaves, from three to five days old, before they have attained their full size, and causes somewhat translucent olive-green or blackish-green spots, which are sometimes so numerous that the whole leaf blackens and shrivels up. When young plants are severely attacked their tops bear only blackened dead leaves. It may happen, however, that as the leaf increases in size the growth of the fungus does not keep pace with it, and the original spots may then dry up and split or fall out, leaving holes in the leaf or lesions extending from the margin. This

perforation and tearing of the leaves occurs most generally on old trees. The fungus also attacks the leaf stalks and green stems, which become swollen in the diseased zone, the swellings subsequently cracking and forming small cankers; these swellings are at first green, but become black later.

The spots on the leaf are at first translucent. They then become dark green, or olive-green, and velvety, owing to the development of an enormous number of minute erect stalks (conidiophores), on which the spores (conidia) of the fungus are produced. On old spots the centre may be yellow, the velvety covering being confined to the margin. On the leaf-stalks and twigs the fungus forms a superficial weft of hyphae from which the conidiophores arise.

The form described above is the first, or conidial, stage of the fungus. A second (pycnidial) stage appears round the edges of the holes on the older leaves in the shape of minute black points, sometimes so close together that they form a complete ring. A third (perithecial) stage appears on old leaves one to two months after they are full-grown; in this stage the fungus causes small brownish areas, scattered over the leaf, and the fructification is produced as a black circular patch, up to four millimetres in diameter, in the centre of each brown spot.

The disease attacks old and young trees alike, but it does most damage to young foliage. Stahel, who has investigated the disease in Surinam, states that the spores of the second and third stages are of minor importance in the propagation of the disease, and that it is spread chiefly by the conidia. The conidia germinate in two hours if placed in water, and, if sown on an immature leaf, the germ tubes have penetrated into the leaf in ten hours. But if allowed to dry they die in fifteen hours.

According to Stahel, the disease is perpetuated by the continuous production of spores (conidia) on immature leaves. *Hevea* produces new shoots several times in the course of a year, and this occurs at different times on different trees, or even on different parts of the same tree. Hence there is always some young foliage present on which the conidial stage can develop and so ensure the continuance of the disease. He therefore advises that, for a period of three or four weeks, all the new shoots which appear should be cut off,

so that the *Fusicladium* spores will not be able to fall on leaves in a condition fit for infection, and will consequently die. In that way the fungus will be eradicated.

Stahel recognises that the ascospores, *i.e.* the spores of the third stage, which develop on old leaves, will, if they alight on young leaves, give rise to the *Fusicladium* again, but he holds that, as the number of ascospores is small, the infection from that source will not be extensive, and can be met by another pruning.

It is recommended that the young shoots should be cut off with a Cacao knife, and it is estimated that a cooly should be able to finish one or two large trees, or more small ones, in a day. It is, of course, essential that all plantations should carry out this measure at the same time, otherwise a plantation which has been treated will be reinfected from its neighbours. Judged by experience in the East, the method would scarcely appear to be practicable, and the reasons on which it is based do not impress one as possessing a very high degree of probability.

Bancroft, after visiting Surinam in 1916, described the condition of the Rubber estates there as follows. "[The disease] appeared in epidemic form on certain plantations in 1914, affecting principally the young trees. Subsequently it spread to other plantations, and it is now present on every estate on which *Hevea* is grown. On the majority of estates the trees are badly affected and are dying in large numbers, some estates having lost in certain areas one-third of the total number of trees. Trees of all ages are affected, and there appears to be no sign of the disease diminishing in any respect. Tapping operations have for the most part been suspended owing to the great reduction in the yield of latex. Several cultivators who possess *Hevea* mixed with coffee intend to remove the *Hevea* and to cultivate coffee only."

The disease appeared in British Guiana about the same time as in Surinam, *i.e.* about 1907. In 1917 it was stated that a fair proportion of the cultivated *Hevea* was only slightly affected, and on some plantations where the disease had been prevalent it had shown signs of diminishing. On the other hand, on other plantations there was no indication of any reduction of the disease. Trees supposed to be situated

PLATE III.

LEAF AND STEM DISEASES

fifty miles from any other known *Hevea* trees had become infected.

In Trinidad the disease first became noticeable in 1916, when considerable defoliation occurred on several estates in widely different parts of the island. In the following year it was more generally distributed, and a number of trees had been killed by the repeated defoliations.

The available evidence indicates that this disease is present wherever *Hevea* is cultivated in South America, and that it occurs on many, if not all, of the species of *Hevea* growing wild in the jungle. It has caused the greatest amount of damage in Surinam, where it is now questionable whether *Hevea* can be cultivated at a profit.

In addition to the removal of diseased shoots spraying has been recommended as a remedy, and it has also been suggested that some system of smoking, which would cause the trees to shed all their leaves, might get rid of the fungus. The latter method, however, would probably not have the desired result, if, as stated by Kuyper, the conidia are produced on green stems as well as on the leaves. But it does not seem likely that it will be possible to eradicate the fungus so long as the cultivated trees are liable to infection from the wild *Heveas*.

The names which the fungus has received are fairly numerous. The perfect or third stage was named *Dothidella Ulei* by Hennings in 1904, and the conidial stage *Fusicladium macrosporum* by Kuyper in 1911. Specimens of the conidial stage sent to Kew from British Guiana were named *Passalora Heveae* by Massee. Stahel prefers to regard the conidial stage as a *Scolecotrichum*, and has named the perfect stage *Melanopsammopsis Heveae*.

Bird's-eye Spot

(*Helminthosporium Heveae*, Petch)

This disease frequently attacks the leaves of nursery plants, but has rarely been found on older trees. The nursery plants are usually affected when they are about three or four feet high. The fungus causes minute spots which are at first purple, but as they increase in size they become white and semi-transparent, surrounded by a narrow purple-brown

border (Plate III., Fig. 4). The mature spots are generally circular. As a rule, they are small, not exceeding five millimetres in diameter, but they may occur in large numbers on a single leaf. They are scattered all over the leaf in no particular order. The fungus breaks through the epidermis, and appears on either side of leaf in the form of minute black points on the white spot. Each of these points is a cluster of minute stalks on which the spores are produced, or it may be only a single stalk. The spores are, for fungus spores, comparatively large (up to a fifth of a millimetre long), and they may often be detected with a simple lens, as long, narrow, brown, and shining objects lying on the surface of the white spot.

This disease has been known in Ceylon since 1905, and it is periodically reported on nursery plants. The young plants are not defoliated by it, and they do not appear to suffer any damage. As a rule, it has caused so little injury that no treatment has been considered necessary. Should it prove serious, the plants should be sprayed with Bordeaux mixture. The disease has also been recorded for South India and Malaya.

Shot-hole Leaf Disease

The name "Shot-hole" disease is usually given to a leaf disease which causes small circular holes in the leaf. One such disease on leaves of *Hevea* has been described by Vincens, who observed it on the leaves of nursery plants at Para. It formed small circular spots not exceeding five millimetres in diameter, more or less translucent, with a slightly raised violet or brown rim, surrounded by a pale zone. When the spots attain their full size the central dead area dries up and falls out, leaving a circular hole margined with brown. The spot resembles that caused by *Helminthosporium Heveae*, but it is usually larger, and in the case of the *Helminthosporium* the centre does not, as a rule, disappear.

In general, only a few leaves are attacked, and the spots are not numerous. It has, however, been observed in a more serious form on young, poorly grown *Hevea*, under dense shade. The leaves in that case were literally riddled with holes.

Several fungi have been found on these spots, but it has not been decided which of them causes the disease. The species which occurs most frequently is a *Scolecotrichum*, *Scolecotrichum Heveae*, which Vincens considers the principal agent. Other fungi which are also found on them are *Fusarium Heveae*, *Aposphaeria Ulei*, and *Zygosporium paraënse*.

Catacauma Huberi (P. Henn.), Theiss. and Syd.

This fungus was originally found on leaves of young *Hevea* at Para. According to Vincens, it is very common in the Amazon valley, but it does not cause any serious damage. It has not been recorded outside South America.

Catacauma Huberi attacks full-grown leaves. It forms shining black crusts, up to a centimetre in diameter, on the under side of the leaves, with corresponding pale green patches on the upper surface. As a rule there is a central black crust, or stroma, from five to ten millimetres in diameter, surrounded by a number of smaller stromata arranged round it in a circle, and separated from it by a pale green zone. Sometimes a second circle of small stromata appears round the first.

The leaves do not appear to suffer to any notable extent from the presence of this parasite, which only kills the tissues below it very slowly. Those leaves which are strongly attacked, and covered with the stromata of the fungus, fall a few days earlier than sound leaves.

Rim Blights

Three different fungi attack the leaves of *Hevea* and cause diseases which may be conveniently known as Rim Blights, since their effect is to produce a narrow white or brownish zone, about a centimetre wide, extending all round, or partly round, the margin of the leaf. Two of these diseases are so much alike in general appearance that they can scarcely be distinguished from one another without a microscopical examination and determination of the fungus concerned. But though their effects are so similar, the fungi are quite different, and there is, as yet, no evidence that there is any relation between them. The three diseases have been

recorded from widely separated localities in Ceylon, and in no case have they caused serious damage. At present they are not generally distributed, but, as they have only recently been discovered, it is too early to generalise on their distribution and effect. On a tree which has been attacked for some time the effect is very striking, as practically every leaf is margined with brown or white. But, according to the observations hitherto made, the leaves do not fall off before the normal wintering.

Ascochyta Rim Blight

(*Ascochyta Heveae*, Petch)

In the first stage of this disease the leaf shows numerous minute, yellowish spots, crowded together in groups which extend from the margin inwards between the veins. Some of the spots near the edge of the leaf then become reddish-brown, and merge into one another to form a dry, brown or greyish-brown patch, with a purple-brown border. These spots may be circular and situated near the margin, but more usually they extend from the edge of the leaf inwards towards the mid-rib between the veins. Finally, the dry spots extend along the margin and fuse with one another, so that the leaf is edged with a discoloured zone sometimes all the way round. When old this zone becomes white or brownish-white. Its inner edge is not straight, but bends inwards between the veins, and it is limited by a narrow, red-brown or purple-brown line (Plate III., Fig. 5). When the dry margined zone is fully formed numerous yellow spots are still present in the green tissue towards the centre of the leaf, where they can easily be seen if the leaf is held up to the light. The fructifications of the fungus appear as minute black points on the white marginal zone.

This disease attacks the leaves soon after they have matured; and the fully-developed stage, when all the leaves of the tree are white-edged, may have been reached by June. In one small affected area it has been noted that the disease begins each year on one particular tree, and spreads from that to its neighbours.

Sphaerella Rim Blight

(*Sphaerella Heveae*, Petch)

The course of this disease closely resembles that of the previous one, the chief points of difference being that (1) the minute yellow spots become thickened, and purple or purple-brown before merging into one another; (2) the line which bounds the inner side of the marginal diseased area is slightly thickened or elevated; and (3) the zone itself becomes yellow-brown and finally grey. As in the previous disease, the fructifications appear as minute black points on the marginal band; they are usually more clustered in this case than in the case of the *Ascochyta*.

This disease has only been recorded once, in Ceylon, in 1917, a group of about half-a-dozen trees being attacked.

Guignardia Rim Blight

(*Guignardia Heveae*, Syd.)

This disease differs from the two foregoing in that the dry marginal zone is, as far as is yet known, pale brown, and does not become grey or white. The affected part of the leaf forms a triangular patch at the tip with a flat base extending transversely across the leaf, and runs down each side towards the base as a band, about one centimetre wide. The inner edge of this zone is purple-brown, and, as in the other rim blights, it bends in and out between the veins (Plate III., Fig. 3). There are no yellow spots in the leaf, but the purple-brown inner edge of the diseased area has a narrow yellowish-green band running along it on its inner side. This band is readily seen on holding the leaf up to the light.

In the known cases of this disease in Ceylon it was particularly noticeable that the marginal diseased area never extended to the base of the leaf; at most it covered two-thirds of the length. The injury caused was negligible, as it occurred on old trees, and on old leaves shortly before the time of leaf-fall.

This disease has also been found in Singapore.

Indeterminate Leaf Spots

Towards the close of its annual cycle the leaves of *Hevea* frequently become discoloured in irregular patches, or torn and more or less dilapidated. This is very liable to occur on trees exposed to strong winds, and in Ceylon it appears to be more usual on *Hevea* interplanted through Tea, or on old Tea land, than on trees in other situations. One of the commonest appearances is a dry, brown, irregular area extending back from the tip of the leaf, while in other cases similar patches extend from the margin inwards over the leaf blade, or both types may be present at the same time. These patches, as a rule, have no definite shape and no well-defined margin, hence they are best classed as indeterminate. When they are old they often split or tear towards the mid-rib, and thus the leaves become ragged. Sometimes the tip breaks off altogether.

How far these appearances are to be attributed to the direct action of parasitic fungi is doubtful. Several species of fungi are to be found on such leaves, many of them only saprophytic, and in those cases in which parasitic fungi have been identified it has not been found possible to correlate these fungi with any definite type of injury. It would appear probable that the initial injury is the result of the action of the weather on the thin leaf, and that the fungi subsequently attack the damaged leaves.

The leaf figured on Plate III., Fig. 6, illustrates the kind of injury in question. On the tree from which that specimen was taken the leaves bore irregular spots, one to two centimetres in diameter, or large dead patches extending inwards from the margin, or similar patches extending backwards from the tip and often involving half the leaf. The dead patches were usually torn, and the diseased tissue had in many instances fallen out. Frequently the outer half of the leaf had disappeared completely. The affected areas were dry, greyish-brown, with a purple-brown, somewhat diffuse margin. In this instance the fungi present were *Colletotrichum Heveae* and *Phyllosticta Heveae*.

In other instances in which similarly affected leaves have occurred the fungus of Grey Blight, *Pestalozzia palmarum*, has been found on the dead parts of the leaf. The leaves

bear grey or brown dry areas, extending back from the tip of the leaf for about two inches, or similar patches stretching inwards from the leaf margin, and angular spots of varying size scattered over the leaf, all bordered by purple-brown. The larger spots are usually broken, and the marginal diseased patches torn. In one case the dead areas at the tips of the leaves split longitudinally along the mid-rib.

Rutgers has recorded a case, from Java, in which a similar effect was produced by *Phyllosticta Heveae*. The dead patches extended from the tips or from the margin of the leaf, and were brown, sharply defined from the sound green parts of the leaf. The plants affected were nursery plants, and in such cases there is considerable doubt whether the conditions under which the plants are grown do not largely influence the attacks of different fungi. Nurseries are usually shaded, and consequently the young plants are grown in a highly humid atmosphere which favours the development of fungi and at the same time renders the plants more susceptible. In the case noted it was determined that infection was only possible under conditions of high humidity, and then only on young leaves. This fungus was originally recorded from Java by Zimmermann.

Brooks has also recorded the occurrence of a *Phyllosticta* on the margins of *Hevea* leaves in Malaya, causing a brown discoloration from the margin inwards. Inoculations showed that it could act as a weak parasite.

When the shade is removed from nurseries the young plants often appear to have been attacked in a wholesale manner by leaf disease. The leaves bear large, white, semi-transparent patches of varying shape and extent, dotted with minute, black fructifications of various fungi. As a general rule these fungi are not the cause of the dead patches, but have only developed on the leaves after they have begun to die. The patches are usually due to the action of sunlight on the young leaves. As the cadjan shade decays, it allows the sunlight to penetrate through the cracks and fall on the previously shaded, tender leaves, with the result that they are injured in parts only ; and feebly parasitic or saprophytic fungi subsequently grow on the injured spots. In some instances the leaves of young nursery plants have been found to be distinctly burnt, an effect which is to be attributed to

the focussing of the sun's rays on the leaf by drops of water on the cadjan screen.

Red Rust

The alga which causes the disease known as Red Rust on Tea has also been found to attack the leaves of *Hevea*, though, as a rule, the resulting damage is inconspicuous. It causes small, circular, purple spots, on which the fructifications of the alga (*Cephaleuros*) are produced. The latter are minute, erect, red hairs, which are crowded together on the spots and give them a velvety appearance. Sometimes, however, the effect is more noticeable. In the worst case of Red Rust yet observed the whole tree had a generally unhealthy appearance, its leaves being curled, and mottled green and yellow, the yellow areas being diffuse and not definite spots. The fructifications of the alga occurred on small spots as already described, but, in addition, the leaves had cracked here and there, and the red hairs were present in lines along the cracks. Only a single tree was affected in this way, and it is probable that, as in Tea, the severity of the attack was to be attributed to a previous general unthriftiness of the tree. It is generally held that Red Rust is a serious disease only on weak plants. No other disease could be detected on the tree, and in the following year it did not show any signs of Red Rust.

Brooks has recorded the occurrence of *Cephaleuros* on leaves of *Hevea* in Malaya.

Abnormal Leaf-fall

The most serious leaf disease which has yet made its appearance in the Rubber plantations of the East is that which is known as Abnormal Leaf-fall. In Ceylon and South India, shortly after the rains of the South-West Monsoon have set in, *i.e.* about the beginning of July, the trees may, if the rains are continuous, begin to shed their leaves, and this may be continued until August. This effect is caused in each country by a species of *Phytophthora*, which rapidly spreads through the plantations until the disease assumes epidemic proportions. As these Phytophthoras attack not only the leaves, but also the fruits, green branches, and stems, the full

account of this leaf-fall has been included in a separate chapter on *Phytophthora* diseases.

Another abnormal leaf-fall has been observed in Ceylon on several occasions, but has never affected any large area. It usually occurs on young foliage, shortly after the leaves are full-grown, and more especially if heavy rains occur during the production of new leaves after wintering. On the young leaves large, irregular, blackish-green, watery-looking patches occur, often along the mid-rib. Older leaves may turn yellow, and then olive or brown. Black spots, often with a grey centre, appear on the veins and mid-rib. The leaf-stalk turns dark brown or black, along part or the whole of its length, and may bear dry grey areas in the middle of the discoloured region. The leaves fall off, sometimes as whole, or the leaflets separate from the leaf-stalk, though all the parts fall at the same time. There is usually a slight covering of white mycelium on the back of the leaf. The fungus in this case is *Gloeosporium alborubrum*, and its fructifications appear in the form of minute pinkish-red pustules, particularly along the veins and on the leaf-stalk.

The disease may spread from the leaves to the green ends of the branches and kill them back. In one instance the leaf-stalks bent at the point attacked, and where the leaves came in contact with the green stem they communicated the disease to the latter. That case, however, appears to have been an exceptional one. In general, the disease is conveyed to the green part of the branch by spores, or, in some cases, by travelling down the leaf-stalk.

Gloeosporium alborubrum sometimes attacks the fruits, and produces a fruit disease similar to the *Phytophthora* fruit rot. Its effect differs in that the fruit wall does not become as soft as in the latter disease, and, in the most advanced stage, dries, and becomes greenish-grey and minutely wrinkled. In one attack, on nearly ripe fruits, many of the fruits dehisced normally, though the seed was "light," *i.e.* the kernel had shrivelled up. The pustules of the *Gloeosporium* appear all over the affected fruits, and in some cases are so numerous that they coalesce and cover the wall with a continuous pinkish-red layer of spores.

The effect of *Gloeosporium* on the young leaves closely resembles that of *Phytophthora*; and as *Gloeosporium albo-*

rubrum very frequently occurs on leaves and fruits which have been previously attacked by *Phytophthora*, it would appear open to question whether in the disease described above the *Gloeosporium* is not merely a follower. But as examination has not demonstrated the presence of a *Phytophthora* in these cases, it is probable that the *Gloeosporium* is the primary cause.

Arens has recorded an abnormal leaf-fall in Java, which he attributed to *Gloeosporium*. In one case it affected five trees; in another two trees were attacked, one of which lost all its leaves, while the other, which stood close to it, was only partly defoliated. Both cases occurred at the same time, and in each the trees had just acquired their new foliage after wintering. The appearance of the fallen leaves and leaf-stalks was identical with that described above. Arens decided that the *Gloeosporium* in these cases was *Gloeosporium elasticae*. He was unable to produce the leaf-fall by inoculating young leaves with the spores of the fungus.

Brooks observed a leaf-fall caused by *Gloeosporium alborubrum* in Malaya, and described the occurrence as follows: "Where *Gloeosporium alborubrum* occurs on recently unfolded Rubber leaves it causes them to shrivel from the margin and fall rapidly from the tree. On a few mature trees growing in low-lying land I have seen this fungus so abundant at the time of unfolding of the leaves after 'wintering' that the ground below was thickly carpeted with the leaves which had been shed. Leaves of *Hevea brasiliensis* at the time of unfolding are of delicate texture, and are much less resistant to fungoid attack than when fully developed."

Another *Gloeosporium* leaf-fall was found in Ceylon in 1905. It attacked young plants, about a foot high, in the nursery, the leaves turning yellow-green, then yellow, and finally falling off. There was a general discoloration and death of the whole leaf blade, not, as is the more usual in leaf diseases, a formation of isolated diseased patches. The spore pustules of the fungus appeared on either side of the leaf as minute pale-brown masses. The fungus was named *Gloeosporium Heveae*. A diminution of the shade made the conditions less favourable for the development of the fungus, and the leaves which were subsequently produced were not attacked.

Several instances of leaf-fall have been recorded which could not be attributed to *Phytophthora* or *Gloeosporium*. In August 1909 an extensive fall of leaf occurred on some estates in Ceylon. In most cases the trees were only partly defoliated, the leaves falling especially from the outer branches and leaving bare shoots all over the outside of the head. In some instances all the leaves were shed, while in one case, where the trees were exposed to the south-west wind, they became bare on the south-west side only. As a rule the leaves were green when they fell, and they did not show any signs of a fungus attack. This year was an exceptionally wet one in the districts in which the leaf-fall occurred, and it was concluded that the fall of leaf was attributable to the effect of the heavy rainfall. The rains ceased towards the end of August, and the trees put out new leaf in the following two months. Rutgers, in Java, has recorded a widespread occurrence of leaf-fall in which no fungus could be detected, and attributed it to the same cause. Similarly, Dastur states that, in a leaf-fall observed by him in Burma, the falling leaf-stalks were healthy and the leaves did not become curled or flaccid, and he was inclined to attribute it to excessive humidity.

A sudden fall of green leaf from a single tree in wet weather may be the result of an attack of root disease. One such case was observed at Peradeniya in 1917 at the beginning of an attack of *Fomes lignosus*; and trees which are said to be "always" the first to be attacked by "leaf-fall" are frequently found to be suffering from the attack of a slow-acting root disease, *e.g. Fomes lamaoensis*.

When timber is burnt among Rubber the hot smoke and gases from the fires may cause a fall of leaf from the neighbouring trees.

Mildew

The term "mildew" is usually applied to fungi which form superficial white powdery patches on leaves and green stems. A large number of these fungi is known, all of them strictly parasitic on the plants on which they occur; some of them are the cause of serious diseases in temperate countries, as, for example, the Hop mildew, Oak mildew, Gooseberry mildew, etc., while in the Eastern Tropics the Citrus mildew

often kills back orange trees. Though the bulk of the fungus is external, it gives off branches which penetrate into the host plant, and ultimately kill the leaves and green twigs.

A mildew has been found on *Hevea* in Java, and is said to occur on Rubber throughout that country, but it has not yet been reported from other Rubber-growing countries. It attacks the trees just after "wintering," and the resulting damage depends to a great extent on the stage of development of the leaves at the time of attack.

The very young leaf of *Hevea*, when first unfolded, is brown and shining. When the leaves are attacked in that stage they become dull and faded, and in some cases the tip and sides of the leaflets curl underneath. A few days later the leaflets fall off, not all at the same time, but in succession. The leaf-stalk remains attached to the twig for some days longer, and then falls. On some of the leaves part of the mid-rib and the lateral veins on the under surface are covered with a fine white coat, while in severe attacks the white covering spreads over part of the adjacent surface of the leaf, and sometimes extends on to the upper side and over the apex of the leaf-stalk.

As the leaves in this stage are very small and tender, they quickly dry and shrivel up, and nothing much is noticeable on the ground beneath the affected trees as a rule. But if attention has been drawn to these leaves on the ground the disease can generally be detected by an examination of those still on the tree, or by the condition of the young branches.

If the leaves are attacked when they are half-grown and have become green the effect is somewhat different. The leaves become dull and yellowish, the tip of the leaf curls under and sometimes dies off, and the edge of the leaf does not develop normally, but becomes distorted and irregularly notched. As these half-grown leaves are more resistant than the very young leaves, many of the leaflets do not fall off when attacked in this stage. Some leaves lose only one leaflet, some two, out of the normal three. Consequently the twigs bear leaf-stalks from which all the leaflets have dropped, and others which retain one or two of them, and the latter subsequently complete their development normally. As in the case of the younger leaves the fungus occurs on the under surface; it is generally more easily discernible than on the

former, but sometimes it is scanty even on the half-grown leaves, and can only be detected with the aid of a microscope.

When fully-developed leaves are attacked they do not fall and are not distorted. They then bear velvety discoloured spots, in this case chiefly on the upper surface, on which fine superficial threads can be detected with a lens; these subsequently become more conspicuous owing to the formation of conidia which give the spots a white powdery appearance. Similar patches also occur on the tips of the green shoots.

The effect on the tree varies according to the severity of the attack and the stage of development attained by the leaves at the time. If the leaves are just shooting and the attack severe, the tree may become almost leafless again in a very short time. If the attack is less severe, or the leaves half-grown, only part of the foliage is shed, and the crown becomes more or less thin. If the whole of the tree has not wintered at the same time, the effect may appear to be confined to one side of the tree, or to one branch, that being the only part in young leaf at the time of attack.

The occurrence of numerous leaf-stalks which bear only one or two leaflets, and those distorted and crumpled, is a special feature of this disease.

The fungus attacks the young blossom especially severely, and the growth on the inflorescence may be so luxuriant that it appears as if covered with flour. The flowers then do not develop and no fruit is formed.

As is usual with mildews in the Tropics, only the *Oidium*, or conidial, stage has been found. The conidia are barrel-shaped, and occur generally singly at the apex of short stalks. They measure $28\text{-}42 \times 14\text{-}23\mu$.

The disease usually occurs on old Rubber in tapping, but it has been found on two-year-old trees and on seedlings just sprouted. In the latter case the plants died.

Species of *Oidium*, or of mildew fungi in general, are usually confined to a limited range of host plants, often to plants belonging to the same natural order. There can be no doubt that the mildew which now attacks *Hevea* has spread to that plant from some allied species of flowering plant, and is in process of adaptation to its new host. Mildews have been recorded in the Tropics on *Euphorbia hirta*, *Euphorbia*

Rothiana, *Phyllanthus Niruri*, *Phyllanthus reticulatus*, and *Jatropha Curcas*, all of which are members of the natural order *Euphorbiaceae*, to which *Hevea* belongs. The first three of these are common weeds, while the fifth is a very common hedge plant. But attempts to infect *Hevea* seedlings with the mildews from *Euphorbia hirta* and *Phyllanthus Niruri* in Ceylon have failed.

Sooty Moulds

The planter is sometimes alarmed by a general blackening of the leaves of the Rubber tree. Frequently only a single tree exhibits this appearance, but in some cases a group of two or three trees is affected. As a rule, the blackening occurs on the upper surface of the leaf only, the lower side remaining green, and the leaves do not fall off. On examination it is found that the blackening is due to a thin sheet of fungus tissue overlying the surface of the leaf, and this sheet, at least in the thicker parts, can be peeled off, leaving the surface a normal green. When the leaf is dried the black sheet cracks and scales off. The fungus is not always confined to the leaves, but may extend over the green shoots. The black colour is the actual colour of the fungus, not a discoloration of the plant.

Fungi of this type are known as Sooty Moulds. They do not live at the expense of the plant, but on the secretions of scale insects which are present on the leaves. The insects will usually be found to be present in large numbers, generally in the form of small, oval, green, or brown scales, adhering to the leaf, more particularly along the veins.

These fungi do not cause any noticeable damage. The way in which they readily separate from the leaf shows that they are chiefly superficial and do not penetrate into the leaf tissue, though it has been proved that, in some cases, they give off minute projections which pierce the epidermis and help to fix the film to the surface. However, this penetration has little effect on the leaf, as is clear from the fact that the leaf itself is not discoloured and does not fall off. Any small damage which may result from the growth of these fungi is indirect; the black film cuts off part of the light which would reach the leaf under normal conditions, and so diminishes in some degree the ability of the leaf to manufacture food.

Obviously, since the fungus grows on the secretions of the scale insects, it would be necessary to get rid of the latter if it were thought desirable to remove Sooty Moulds. But the effect of these moulds is quite negligible, and the adoption of any treatment against them is not warranted by the available evidence. Whether it would ever become advisable to adopt measures against the scale insects, on account of the damage done by the latter, is another question.

Sooty Moulds tend to be more prevalent during dry seasons, and to disappear during the rains. This is perhaps due to the effect of the weather on the insects.

Green *Hevea* shoots and fruits frequently, almost always, bear other fungi of the same class as the Sooty Moulds, but as they form a much thinner film, they are not so conspicuous. These species appear in black cloudy patches, in varying depth of colour, over the green tissue, but not completely hiding it. The patches cannot be peeled off, and no fungus threads can be detected except by a microscopic examination ; indeed, they appear to be stains on the green tissue rather than a fungus covering. The tissue underlying these stains is quite normal, and yields latex when cut, and is thereby distinguished from the blackened, soddened wall of fruits attacked by *Phytophthora*. No scale insects accompany these fungi ; they live on the secretions of the "extra-floral" nectaries which are situated at the base of the *Hevea* leaf. The patches frequently bear minute, black points, which are the fructifications of the fungus. In Ceylon the species which is found on green *Hevea* shoots is *Chaetopeltopsis tenuissima*.

Nodules on Leaves

(*Aschersonia*)

Another fungus which accompanies scale insects occurs fairly frequently on *Hevea* leaves and green shoots in Ceylon. It is almost hemispherical in shape, and forms rather hard smooth warts up to five millimetres in diameter, attached to the leaf by a flat base. The colour varies, from pale yellow, or yellow-brown when young, to black when old. Internally it is yellow or orange-yellow (Plate VI., Fig. 10). The fungus does not penetrate into the leaf, and is easily detached from it.

These fungi are not parasitic on the leaf but on the scale insects. Each wart is developed over, and devours, a single scale insect. They are therefore beneficial, and assist the planter by destroying insects which might do damage to the tree. They belong to the genus *Hypocrella*, but it is usually the lower, or *Aschersonia*, stage which is found on the leaves of *Hevea*. Many species of *Hypocrella* occur in the Tropics, all of them parasitic on scale insects; the commonest one on *Hevea* is *Hypocrella Reineckiana*.

SUMMARY

LEAF DISEASES

South American Leaf Disease

(*Fusicladium macrosporum*, Kuyper)

Identification.—Young leaves covered with somewhat translucent, olive-green or blackish-green spots, sometimes so numerous that the whole leaf blackens, withers, and crumples up: spots velvety with minute erect hairs (conidiophores). Older leaves perforated, the holes surrounded with small black points. On the green twigs swellings which become black. Affected leaves fall off.

Occurrence.—Attacks leaves of all ages, but is especially destructive to young foliage, three to five days old, before the leaves have fully developed. Trees may be repeatedly defoliated, and die in consequence. Only known to occur in South America, where it attacks both wild and cultivated *Hevea*.

Treatment.—See p. 79.

Bird's-eye Spot

(*Helminthosporium Heveae*, Petch)

Identification.—Spots small, circular, not more than five millimetres in diameter, white and semi-transparent, surrounded by a narrow purple-brown line (Plate III., Fig. 4).

Occurrence.—Common on nursery plants, about three or four feet high; rare on old trees. Known in Ceylon since 1905, and reported from South India and Malaya.

Treatment.—Has not been considered serious enough to warrant treatment.

Shot-hole Leaf Disease

(? *Scolecotrichum Heveae*, Vincens)

Identification.—Spots at first circular, not exceeding five milli-

metres in diameter, more or less translucent, with a violet or brown rim, and a pale outer zone: the centre dries up and falls out.

Occurrence.—Found on nursery plants, and on young poorly-grown *Hevea*, at Para, South America.

Catacauma Huberi (P. Henn.) Theiss. and Syd.

Identification.—On the under side of the leaf, a black, shining crust, up to a centimetre in diameter, surrounded by similar smaller patches arranged in a circle. The corresponding area on the upper side of the leaf is pale green.

Occurrence.—Attacks full-grown leaves, which do not appear to suffer notably, and, if severely attacked, fall only a few days before the normal wintering. Common in the Amazon valley: not recorded in other countries.

Ascochyta Rim Blight

(*Ascochyta Heveae*, Petch)

Identification.—Leaf margined with a white, or brownish-white, zone, about a centimetre wide, which bends in and out between the veins; minute yellow spots between the veins, seen on holding the leaf up to the light (Plate III., Fig. 5).

Occurrence.—Attacks full-grown leaves at any age. The leaves do not fall prematurely. Only recorded from Ceylon.

Sphaerella Rim Blight

(*Sphaerella Heveae*, Petch)

Identification.—Resembles Ascochyta Rim Blight; the inner edge of the marginal zone is slightly thickened, and the zone yellow-brown and finally grey.

Occurrence.—Recorded once, in Ceylon.

Guignardia Rim Blight

(*Guignardia Heveae*, Syd.)

Identification.—Marginal zone brown, with a narrow, purple-brown, inner edge, followed by a narrow yellowish-green band, seen on holding the leaf up to the light (Plate III., Fig. 3).

Occurrence.—Found in Ceylon on old leaves shortly before the time of leaf-fall; occurs also in Singapore.

Indeterminate Leaf-spots

Identification.—Brown, dry, irregular areas, extending back from the tip of the leaf, or from the margin towards the mid-rib, frequently irregularly torn (Plate III., Fig. 6).

Occurrence.—On old leaves towards the close of the year. Probably due, in part, to climatic causes. The fungi found on these spots include *Phyllosticta Heveae, Colletotrichum Heveae, Pestalozzia palmarum*, etc.

Red Rust

(*Cephaleuros* sp.)

Identification.—Spots small, circular, purple, velvety, with minute, erect, red hairs.

Occurrence.—Fairly frequent on old leaves of *Hevea*, but does not cause much damage. Its effect may be greater if the tree is generally unthrifty.

Abnormal Leaf-fall

An abnormal fall of full-grown leaf, *i.e.* a leaf-fall at other than the normal time of wintering, may be due to one of the following causes. There is no certain way of distinguishing between these without a microscopical examination.

(1) *Phytophthora* leaf disease. This usually occurs during the monsoon rains, and is accompanied, or preceded, by pod disease. It soon becomes general over the estate. It is described in the following chapter.

(2) *Gloeosporium* leaf disease. Generally occurs in wet weather soon after the new leaf is fully developed. Usually confined to a few trees. Appearance indistinguishable from the *Phytophthora* disease, but a slight covering of mycelium on the under side of the leaf is present more generally than in the latter. Pink pustules develop along the veins.

(3) Leaf-fall due to excessive rainfall may occur without the intervention of a fungus disease. This may be general over a wide area.

(4) Leaf-fall may occur in the early stage of a root disease, though apparently rarely; isolated trees only are affected.

Mildew

(*Oidium* sp.)

Identification.—Part of the mid-rib and the veins on the under side of the leaf are covered with a fine white coat; without microscopical examination and identification of the fungus this does not distinguish this disease from *Gloeosporium*. The occurrence of numerous leaf-stalks, which bear only one or two distorted and crumpled leaflets, is a special feature of this disease.

Occurrence.—Attacks the very small brown leaves just unfolding, and causes them to fall off. Half-grown leaves lose all, or one or two, of their leaflets, and the remaining leaflets are irregularly distorted.

On fully-formed leaves white powdery patches are produced. Hitherto recorded only from Java.

Sooty Moulds

Identification.—A black film on the upper surface of the leaf, which scales off when dry.

Occurrence.—Develops on the secretions of scale insects, which may be found on the affected leaves, particularly along the veins, and does not seriously affect the tree.

Treatment.—Not usually required. To prevent the growth of these fungi it would be necessary to get rid of the scale insects.

Nodules on Leaves

(*Aschersonia* sp.)

Identification.—Hard, hemispherical warts, yellow, or yellow-brown, or black, attached to the leaf by a flat base, and easily detached (Plate VI., Fig. 10).

Occurrence.—These fungi grow on and kill scale insects, and are consequently beneficial.

CHAPTER IV

PHYTOPHTHORA DISEASES

Abnormal Leaf-fall and Pod Disease

In the principal Rubber districts of Ceylon *Hevea* sheds its leaves at the end of January, or early in February, in the low country, and a few weeks later at medium elevations. The leaves turn yellow, brown, or red, as in the autumnal changes in temperate climates, and the process is generally known as "wintering." Frequently, apparently more especially when, instead of the normal drought, heavy rains occur in January and February, the wintering is irregular. Neighbouring trees may winter at periods differing by two or three weeks, and even one side of a tree may drop its leaves and acquire new foliage before the leaves on the other side have begun to change colour. In this normal leaf-fall the leaflets are usually disarticulated and fall first, while the leaf-stalk remains attached to the branch and only falls later.

In Ceylon the South-west Monsoon is supposed to "burst" in the latter half of May, and June and July should be months of heavy rainfall. If the rains of May and June are fairly continuous a second fall of leaf may set in about the beginning of July, and if the rains continue through July and August this leaf-fall is continued also. But should dry weather intervene, the leaf-fall ceases. Trees rarely lose all their leaves, but they may lose the greater portion of them, so that the ground is thickly covered with dead leaves, while the trees have a very "thin" appearance.

This abnormal leaf-fall is known to occur in Ceylon, South India, Burma, and Java. It has been referred to as monsoon leaf-fall and second leaf-fall, but the term abnormal leaf-fall appears the most appropriate. In South India its incidence

is similar to that in Ceylon, but a little later, in accordance with the later burst of the monsoon. According to McRae, the trees begin to shed their leaves about a fortnight after the monsoon has set in steadily, and the leaf-fall is most noticeable from the middle of July to the middle of August, by which time the trees cease to shed their leaves to any appreciable extent.

This disease is intimately associated with the fruit rot, or pod disease, of *Hevea*. In all the countries in which abnormal leaf-fall occurs the cause of the principal abnormal leaf-fall is a *Phytophthora* which, in the general case, attacks the fruits first and then passes from them to the leaves and branches.

The fruit rot which occurs in Ceylon was determined to be due to *Phytophthora* in 1905. In that year it threatened to destroy the whole fruit crop, but it was not associated with any marked leaf-fall. An abnormal leaf-fall occurred in Ceylon in 1909, but in August, after the seed had ripened. In 1912 leaf-fall and pod disease occurred together, and it was then determined that that leaf-fall was also due to *Phytophthora*.

The dependence of the disease on climatic conditions during the time the fruits are ripening is very marked in Ceylon. Previous weather conditions do not seem to have any effect. In 1916 a long drought was experienced at the beginning of the year, but the rains which began in May were continued through August and September, with the result that the abnormal leaf-fall was the worst hitherto known. In the following year the monsoon rains were light until the end of July, and nearly all the seed had ripened in the low country before any very wet weather occurred; in consequence, leaf-fall was almost unknown, and the seed crop was a record one. At Peradeniya (elevation 1600 feet) abnormal leaf-fall is uncommon, probably because the fruits ripen in September, about six weeks later than in the low country, and both August and September are usually months of low rainfall.

If heavy rains set in when the pods are nearly ripe they may not be attacked by this disease though their dehiscence may be delayed for several weeks. In 1917 there was almost continuous rain at Peradeniya from September to December. But the fruits which were not fully ripe when the rains began

did not become diseased, though some of them did not split until Christmas.

Fruit disease and leaf-fall occur together in Ceylon, South India, Burma, and Java. Fruit disease due to *Phytophthora* has also been recorded in the Cameroons, but no mention is made of leaf-fall.

Species of *Phytophthora* are responsible for some of the most destructive diseases of cultivated plants. Perhaps the best known is the potato disease, which periodically attacks the potato fields of Europe and America, especially in wet summers, and was the cause of the Irish Famine, and the consequent depopulation of Ireland, in the late 'forties. The close relation between weather conditions and the incidence of a *Phytophthora* disease is a necessary consequence of the mode of reproduction of the fungus. The sporophores, or external mycelium, on the diseased plant bear minute egg-shaped bodies, usually provided with a papilla at the apex. These are known as sporangia. They are easily detached from the sporophores, and can therefore be distributed by the wind. When a sporangium falls into a drop of water, its contents divide into a number of spores which escape through the apex of the sporangium owing to the solution of the papilla. Each spore possesses two cilia, or short threads, by means of which it swims about in the film of water. As the spores are motile, they are known as zoospores. After a short time they come to rest, round themselves off, and germinate as ordinary spores. Thus, in order that a *Phytophthora* may carry out its normal life-processes, moisture in the form of rain, mist, or heavy dew is essential.

Some of the sporangia which are produced are spherical, instead of egg-shaped. Apparently these do not give rise to zoospores, but behave as ordinary spores. They often acquire a thick wall and become resting spores. These are more resistant than the zoospores, and while the latter provide for the rapid dissemination of the fungus in wet weather, the former serve to carry it over the dry season. Resting spores (resting conidia) may be produced among the external mycelium or within the tissues of the host plant. Those within the plant can only be liberated on its decay.

In addition to the zoospores, many species of *Phytophthora* produce a second kind of spore by a sexual process. Such

spores are known as oospores: they are thick-walled, and constitute the normal resting spore.

The Fruit Disease

As already stated, the disease in general begins first on the fruits. Soon after the rains set in, the green fruits (in Ceylon) become a dirty watery green or olive green, either in patches or all over. The patches most frequently begin on the upper part of the fruit, near the stalk, but they may originate anywhere. The diseased patches become blackish and sodden, and this condition extends over the whole fruit. The outer layer of the fruit wall is then soft and rotten, and squashes readily when the fruit is handled. Sometimes drops of latex exude, and form small, black masses of rubber on the fruit. While these changes are going on, a white or greyish film of mycelium appears on the oldest diseased parts and gradually spreads, sometimes until it covers the whole surface. In very wet weather, the mycelium may cover the fruit with a thick white felt. The fruit wall splits along the grooves, but the woody part remains intact at the apex and base, and the fruit does not break up into sections as it does normally. Ultimately, it dries up in the fine weather, and the decayed fruits remain hanging on the tree for a long time, often until after the next wintering. When they fall, they usually leave the fruit-stalk still attached to the branch. In some cases the seeds are not completely formed, and in practically all cases they become rotten.

McRae describes the appearance of the fruit rot in South India as follows. "About a fortnight after the monsoon bursts, the fruits on infected trees begin to show dull ashy-grey portions on their surfaces. The discoloured part is slightly wrinkled and sunk a little below the surface level of the healthy part of the fruit. It frequently appears at the proximal or stalk end of the fruit and gradually extends downwards and laterally until the whole fruit is covered. Sometimes, however, it appears first on the side of the fruit or at its distal end. Several discoloured spots may appear and run together. Drops of latex appear here and there on the surface and gradually turn black. The outer covering of the fruit becomes dark and sodden and infected with a soft

rot. It splits along the three sutures (or cracks), exposing the capsule within and remains attached to it. The capsule often does not split, and the seeds either never form or become rotten. The decayed fruit hangs on the tree for a considerable time, then falls off, leaving the stalk attached to the branch, but it may hang on the tree even till the next season."

The diseased fruits are rapidly attacked by other fungi, and in the advanced stages the fungus growths observed on them are chiefly these secondary species. *Gloeosporium alborubrum* occurs commonly, and forms groups of pinkish-red heaps of spores. *Botryodiplodia*, *Fusarium*, *Nectria*, and *Sphaeronema* may also be present, and cover the fruits with black, white, or red fructifications which mask the *Phytophthora* which is the real cause of the disease.

[It is necessary to interpolate here a word of caution, though it will hardly be needed by those who have had any practical acquaintance with the real fruit rot. Frequently there are submitted for examination, in the belief that they are attacked by *Phytophthora*, green *Hevea* fruits, or green twigs, which bear black patches, usually varying in density from point to point and presenting more or less a cloudy appearance. But if these patches are lightly scraped, the epidermis of the plant beneath them is found to be green and the underlying tissues full of latex. There is no evidence of any injurious effect on the fruits or stems, and the black patches are practically entirely superficial. They consist of fungi which belong, or are related, to the so-called Sooty Moulds, which so commonly cover the leaves of plants in the tropics with a black film. The majority of these fungi do not attack the plant on which they occur, but live on the sugary secretions of insects, etc. In the case of *Hevea*, they are probably dependent on the secretions of the "extra-floral" nectaries which are situated at the base of each leaf. With the aid of a lens, minute black points may be detected on the cloudy patches. These points are the fructifications of the fungus, which in Ceylon is generally *Chaetopeltopsis tenuissima*.]

Leaf-fall

Soon after the fruit rot has set in, the trees begin to shed their leaves. The leaves may first turn yellow, or they may fall when quite green. Sometimes they are mottled, green and yellow, the yellow colour being particularly marked along the veins, or they may be olive or bronzed, with prominent green veins. On young leaves, watery, blackish-green spots appear, and these coalesce and form large patches, either down the centre along the mid-rib or spreading inwards from the margin. The leaves may fall as a whole, or the leaflets and leaf-stalk may separate, but if the latter occurs the parts, in general, fall at the same time. In this respect this leaf-fall differs from the normal leaf-fall, in which the leaf-stalk remains for some time attached to the branch. The leaf-stalk, as a rule, is discoloured and blackish-brown, it may be, only for a short distance, or for the greater part of its length, but in many cases it remains green. The discoloured stalks often bear a small drop of coagulated latex about the middle of the diseased area. In some cases the first sign on the leaf-blade is a similar brown length along the mid-rib. The ground beneath the trees becomes thickly covered with fallen leaves, and the trees may be almost bare, with the rotten fruit conspicuously evident.

The differences in the appearance or condition of the fallen leaves are to be attributed in part to their age and in part to the differences in the way in which the fungus has attacked the tree. Young, fairly tender leaves show more definite spots than the older leaves, if the leaflet is directly attacked by the fungus, *i.e.* if the fungus spore alights on the leaflet and begins to grow there. The fungus, however, in many cases does not attack the leaf-blade. It may attack the bases of the leaflets, *i.e.* their junctions with the leaf-stalk, or it may develop on the leaf-stalk and so cause the leaflets to fall, although no fungus is to be found on them. Hence the fallen leaves are sometimes green and sometimes discoloured.

Once the disease has begun, its spread is extraordinarily rapid provided that the weather conditions remain favourable to the development of the fungus. The white film on the fruit produces innumerable spores and these can be washed off by the rain on to the leaves of the tree. Transfer of the

spores to neighbouring trees is most probably brought about by the splashing of the rain-drops on the diseased fruits. It has been shown that, when a falling drop falls on a film of water, it is the water of the film which is splashed, or forms what is known as the splash drop. These splash drops are shot out to a distance of several feet, and in a moderate wind can easily be carried from one rubber tree to another.

When the drier weather, following the monsoon rains, sets in the trees put out new foliage and appear normal, except for a number of dead shoots all over the crown.

Die-back of Shoots

After a severe outbreak of leaf-fall and pod disease, many of the green shoots are found to have died back, and, according to observations in South India, this dying back may proceed further, along the larger branches, during the ensuing cold weather. McRae has demonstrated that this die-back is also caused by *Phytophthora*, and that the mycelium of the fungus is present in the dead and the living tissues of the branch. On splitting open a dead branch, a dark brown line is found separating the living from the dead part. The mycelium may be found on either side of this line, not only in the brittle dead portion, but also in the tough living tissues. It occurs in the bark, wood, and pith. In some cases it extends only an inch or two along the living part, while in others it is found much further along, especially when fresh young shoots have developed. It has been shown that the fungus invades the branch from the fruit-stalk or *via* the terminal bud. It can, however, attack the green shoot directly, and in the earlier stages of an attack of "leaf-fall" it is often possible to find blackened sunken areas on the green shoots, coincident with the appearance of the disease on the leaves and independent of diseased leaf-stalks.

The mycelium of the fungus lives through the dry weather in the branches which have partly died back. According to McRae, the new shoots which are produced from the living part of these branches in the following spring may begin to wilt about a month later. The leaflets shrivel, dry up, and fall off; the lowest inch or so of the shoot becomes discoloured; and the shoot ultimately dies back to its parent

branch. In many such cases, the mycelium is not in the leaves but in the branch, and it would appear that it is the effect of the fungus within the branch which causes the new shoot to shed its leaves.

It must be borne in mind that this form of die-back is only likely to occur during or after an attack of fruit disease and abnormal leaf-fall. There are many other causes of die-back of the green shoots of *Hevea*, and it is scarcely possible to distinguish between them without a microscopical examination of the dead twigs. Shade is responsible for the death of many branches, especially in the lower part of the tree, while there is reason to suppose that too frequent forking, more especially on poor soils, may have the same effect. Of diseases, *Gloeosporium alborubrum* (see p. 146) and *Phyllosticta ramicola* may cause die-back of the green shoots, and several other fungi are under suspicion.

Preventive Measures

It has already been indicated that the principal cause of the rapid spread of the disease is the development of the fungus on the fruits. Once the disease has begun the fruits serve as the main centres of propagation of the fungus and of distribution of the spores. Any method which would prevent the formation of fruits, or diminish their numbers, would therefore be expected to check to a great extent the spread of the disease, even if it did not exterminate it altogether. Four suggestions have been made with this object in view, viz.: (1) spraying the trees when in blossom to prevent the fruit setting; (2) the adoption of some method of manuring or cultivation which would prevent the trees from flowering or would reduce the number of flowers; (3) the removal of the flowers; (4) removal of the green fruits before the monsoon rains set in.

With regard to the first of these suggestions, it is generally recognised that the difficulties in the way of spraying Rubber trees which are old enough to bear fruit are so great that spraying is practically impossible. To spray the flowers it would be necessary to spray the whole tree, and as the trees are up to fifty feet high, power sprayers would be required. Except in rare instances, power sprayers could not be used on

Rubber estates in Ceylon owing to the lie of the land. Moreover, it would be difficult to spray the flowers effectively, as they are partly protected by the foliage ; and as the lateral branches of the trees generally meet, the whole tree could not be sprayed. The same objections apply to spraying the fruits with Bordeaux mixture to protect them from the attacks of the fungus.

As far as is known, there do not appear to be any cultural operations, applicable to estates, which would tend to reduce the number of flowers or to prevent the trees from flowering. The manurial experiments in progress at Peradeniya, in which the different ingredients are applied in excess on the different plots under experiment, have not as yet shown any such effect. Whether it will be possible to make any deductions from those experiments concerning the effect of the different manures on the incidence of the disease, as distinct from the relative abundance of flowers, is still undecided, because the experimental plots have not yet been attacked. As regards manuring in general, it has been stated that in Ceylon the disease is worst on unmanured Rubber and on old Tea fields, but this does not appear to be the general experience.

Cutting off the flowers has been tried and found impracticable, chiefly because the flowers are situated among the young leaves and cannot be reached without damaging or removing the latter. It is also found that the stalk of the inflorescence is not rigid enough to be cut with a hooked knife, but bends before it unless it is exceptionally sharp. Moreover, the operation entails much unnecessary labour, because not all the inflorescences produce fruits. A calculation by McRae of the inflorescences on the lower and middle branches of the trees, which would be the only ones removed in practice, showed that only 35 per cent of these bore fruit.

Removal of the fruits prior to the rains is the most practicable of the suggestions enumerated, though the expense of the operation is heavy, and in any case it is not possible to cut off all the fruits, as they are scattered at the ends of the young shoots all over the tree and those in the upper part of the crown cannot be reached, as a rule. This was done over small areas on several estates in Ceylon in 1917, the cost of removing those fruits which were accessible being about Rs. 20.00 per acre. There was, however, no opportunity of

judging the efficacy of this measure, as fruit disease was practically absent during the following season. In South India, removal of the fruits has been carried out, together with the cutting out of dead branches ; these operations will be referred to later.

Other ways of combating the disease have been devised, with the object of getting rid of the fungus during the period when it is in a dormant condition, and so preventing it from being carried over to the next season. It is known that resting spores of the fungus are formed on the diseased fruits, and if the latter remain on the tree until after the wintering period, they constitute a possible source of infection in the next rainy season. In Ceylon, in both 1917 and 1918, the first cases of leaf-fall due to *Phytophthora* occurred at the end of January, shortly after the new leaves had appeared. In both these years heavy abnormal rains occurred at that time in some districts, instead of the usual dry weather, and one or two trees were attacked by the disease. In these cases, it was noted that the affected trees bore numerous dried, diseased pods of the previous season, and it is probable that the fungus spread to the new leaf from them. The attack in these cases was a direct one upon the leaf.

McRae has shown that the *Phytophthora* can live through the dry season in branches which have partly died back. The mycelium is found, in a living condition, at the junction of the live and dead tissue, and a few inches along the former. To get rid of this source of infection, dead branches must be cut off, and they should be cut with about a foot of the apparently sound living part of the branch.

The removal of dead branches is now being carried out systematically on many estates in Ceylon as part of the general routine of the estate. It is best done after the trees have acquired their new leaves, so that the cooly cannot make any mistake and cut off living branches, as he would when the trees are leafless. Of course, as has already been pointed out, many branches die from other causes, and it is impossible to differentiate, in the field, between these and the branches killed by *Phytophthora*. Therefore a considerable amount of work will be done which, from the point of view of this disease only, is not necessary. But the removal of dead branches in general is an elementary precautionary measure

in plant sanitation which should be undertaken in any case. The period stated is also the time when the trees most require to be rested, and if this is done, ample labour is available for removing the dead branches.

Removal of dead fruits can be undertaken at the same time. In general it is only found practicable to knock these off. This leaves the fruit-stalk attached to the branch, and herein lies, it is claimed, another source of infection, as the fungus can infect a branch *via* the fruit-stalk. It is, however, impossible to remove all these fruit-stalks, and it may reasonably be queried whether the infection of the branch, when it does occur, had not taken place before the diseased fruits dried.

The dead fruits and the prunings should be burnt.

Experiments on the control of this disease were carried out in South India, in 1917, on blocks of varying size on different estates. In some instances all dead branches were cut off and the wounds tarred, and the new green fruits removed; in others, treatment was confined to the removal of dead branches only.

On estate A, 105 acres of eight-year-old Rubber were treated, all dead branches and most of the fruits being removed, at a cost of about Rs. 19.00 per acre. The leaf-fall was reduced to a very small minimum, so much so that the one tree that shed its leaves to any marked extent was distinctly the feature of the plot. By an oversight, the fruits had been left on this tree, and they were infected by *Phytophthora*.

On estate B, 50 acres of eleven-year-old Rubber, 120 trees to the acre, were treated, at a cost of about Rs. 16.00 per acre. The dead branches were mostly pruned off, but the removal of the fruits was not complete when the monsoon broke. Leaf-fall and fruit disease were severe, and there was little difference between the experimental plot and the control plot.

On estate C, dead branches were removed over an area of 60 acres, while the fruits were removed thoroughly from half the area, and only partially over the other half. The amount of leaf-fall was distinctly less on the first thirty acres, and a little less on the other thirty, than on the control plot. The cost of the treatment was Rs. 9.50 per acre: the

age of the rubber and the number of trees to the acre is not given.

The above experiments would appear to indicate that, in order to check the disease to any marked degree, it is necessary to remove both the dead branches and the ripening fruits, though they do not afford any evidence as to the effect of removing the fruits only. With regard to the objection that it is impossible to carry out these operations over the whole estate in the time available, it has been suggested that the work could be limited to part of the estate in the first year, and the area extended in succeeding years, on the assumption that there would be fewer dead branches to be removed each year on the areas previously treated.

Claret-coloured Canker, Purple Canker, or Patch Canker

This disease was first discovered on *Hevea* in Ceylon about 1903. It has since been found in Java, Sumatra, and Fiji, but there is some doubt whether it occurs in other Rubber-growing countries. It is said to be present in the Federated Malay States, but to be of rare occurrence there.

In the early stages of Claret-coloured Canker, there is, as a rule, very little outward indication of disease. On young trees the bark may appear darker, but when the tree has acquired a thick, outer, brown bark this is not evident. In many cases the bark exudes a reddish or purplish liquid, which dries in small streaks ; in very wet weather this may occur when only a small patch of bark is diseased, but more usually it only happens after a fairly large area has become affected. When the disease is in an advanced stage, the decaying bark soon attracts numbers of boring beetles, and it is frequently not until then that anything is seen to be wrong with the tree.

In some cases the disease has been discovered by observing that the tree has suddenly ceased to yield latex. This is not invariably a sign of Claret-coloured Canker ; it is more often due to Brown Bast, and may be due to root disease, or, on the other hand, it may not be a sign of disease at all. Many trees cease to yield latex for no apparent reason, and become normal again in the course of a month or two. But

whenever the flow of latex ceases the bark should be lightly scraped here and there, more especially below the tapping-cut, to see whether it is discoloured internally. On the other hand, in probably the majority of cases the flow of latex is unaffected, especially when the diseased patch is not immediately below or on the tapping-cut.

In healthy *Hevea* cortex, if not previously tapped, a green layer underlies the outer, brown, corky bark. Beneath the green layer the cortex is yellowish, becoming whiter near the cambium. In renewed bark the green layer is usually absent, and the outer living layers of the cortex are, in part, a clear red. Frequently this red coloration runs in a narrow zone, just within the cortex (see Plate V., Fig. 5). This clear red coloration is a normal appearance, which persists in the renewed bark for many years.

In cortex attacked by Claret-coloured Canker, the colours are entirely different. On scraping off the outer brown layer, one finds not a green but a black layer, and underneath this the cortex is moist and discoloured. When recently attacked, it is greyish or yellowish-grey, with a well-defined black border, but in advanced stages it becomes claret-coloured or purple-red, and has been aptly compared to the inside of the fruit wall of a ripe mangosteen (Plate IV.). Frequently the diseased cortex is dirty red when cut, but darkens to purple-red soon after exposure. Once it has been seen, it is not possible to confuse it with the red coloration of renewing bark; it is always a "muddy" colour, quite different from the clear, translucent red of the latter, and it is clearly marked off by a black line from the surrounding healthy bark.

The disease begins from the exterior of the cortex and works inwards towards the cambium, spreading out at the same time more or less equally in all directions. It does not, as a rule, run in narrow bands or stripes (Fig. 12). In many cases it is detected before it has penetrated right through the cortex, but if left alone it kills the cortex down to the cambium and spreads laterally, as long as conditions are favourable. It may thus extend over large areas of bark, and ultimately kill the tree, without producing any open wound or giving any outward indication except the bleeding already mentioned. When dry weather sets in, however, the disease generally stops, and the affected cortex then dries up and

CLARET-COLOURED CANKER

Patch exposed by shaving

forms a scale which ultimately falls off. In these cases of "self healing," the resulting damage depends entirely on the extent to which the disease has spread. If it has not penetrated completely through the cortex a scale is formed, of a

FIG. 12.—*Hevea* Canker, caused by *Phytophthora Faberi*; cortex cut away to show the discoloured areas.

thickness depending upon the depth of penetration, but the wood is not exposed. But if it has penetrated through to the wood, a large open wound, exposing the wood, is the consequence. In many instances the dead bark does not fall off,

but is pushed off later by the growth of the callus underneath it from the edge of the wound.

The most serious cases of Claret-coloured Canker are those in which the tree is attacked at the collar. The disease may then run rapidly round the base of the tree and kill it in a few weeks.

When this canker attacks the thin, recently tapped, renewing bark, the diseased tissue often retains the colour of the early stage, *i.e.* it is yellowish-grey, and does not become claret-coloured; but where, as usually happens, it extends from the renewing bark into the untapped area below it, the patch in the latter assumes the typical claret coloration. It is distinguished from Black Thread not only by the colour, but by the fact that it spreads, from the beginning, uniformly in a continuous sheet, and does not at first form small vertical lines which broaden out and unite with one another later. It is important that Claret-coloured Canker should not be confused with Black Thread, as the application of a wash which will cure the latter is usually ineffective against the former, while the use of tar or tar mixtures often makes matters worse.

Bark attacked by Claret-coloured Canker has a peculiar smell which, soon attracts boring beetles, particularly a small brown beetle about the size of the Shot-hole borer. When the disease has been in progress for a few weeks, the decayed patches are usually riddled by this borer.

The *Phytophthora* which causes Claret-coloured Canker is identical with that which causes the similarly-coloured canker in Cacao. It is found on *Hevea* fruits and leaves in Ceylon, and is one of the causative agents of the fruit rot and leaf-fall, while in the case of Cacao it causes the very common brown rot of the fruits, which is responsible for the loss of a high percentage of the crop annually. When *Hevea* is interplanted among Cacao, the Cacao pods serve as a continual source of infection for the *Hevea*. Moreover, the dense shade of the mixed plantation favours the growth of the fungus on both products.

It follows from our knowledge of the life-history of the fungus that the stems of *Hevea* are most liable to infection when they are wet, for the sporangia cannot produce zoospores in the absence of moisture. It is quite clear that in

Hevea Claret-coloured Canker is produced by spores which alight on the stem, and after germination produce a mycelium which gradually destroys the cortex from without inwards; for, in the early stages of the disease, the discoloration begins beneath the outer layer and does not extend to the cambium. The spores, blown by the wind or splashed by the rain, lodge on the bark, and if the stem is sufficiently moist a canker patch is produced at the end of a few weeks. Frequently several patches are found on the same stem, each the result of a separate infection. Attention has previously been directed to the effect of different systems of planting upon the protection afforded to the stems by the crown of the tree. When the trees are closely planted their branches run up more or less vertically, and the rain which falls on the crown is conducted by them down the main stem. Thus the stems are constantly wet during the rains, and the dense shade prevents rapid drying. When the trees are closely planted, thinning out is one of the measures to be adopted against Claret-coloured Canker.

Excision of all the discoloured cortex is the recognised treatment for canker. It is not necessary to cut out more than the discoloured area. All the cortex cut out must be removed and burnt. The wood beneath the diseased cortex need not be cut out. The difficulty in the case of this disease is the discovery of the canker before it has progressed so far that a large area has to be excised. The tapping coolies should be shown what cankered bark is like, and they should be instructed to stop tapping and report any trees which cease to yield latex. Many cases of canker are only discovered by the cessation of the latex flow, and it was formerly not uncommon to find that the cooly had been tapping for weeks on cankered bark from which he could not possibly have obtained a drop of latex.

During the dry weather it is possible to modify the treatment of the canker patches which are present as a result of infections during the rains. The diseased part may then be scraped or cut away so as to remove most of the cankered bark, the cutting being continued until latex begins to appear in minute drops. This is a sign that the limit of the diseased part is being reached, as the cankered part does not yield latex. The remainder of the diseased cortex is then left to

dry up and scale out. Of course, if the disease has penetrated to the wood, the whole of the cankered cortex is cut out.

Canker should be treated when found. No doubt more satisfactory work can be done in dry weather, but if the disease is allowed to run unchecked for the remainder of the year, large areas of bark will be affected and trees probably killed by it.

After excision, the patches should be painted over with a 20 per cent solution of Brunolinum or some similar preservative; and where the wounds extend right through the cortex to the wood, the exposed wood should be tarred to prevent the attacks of boring beetles. The tarring should be continued right up to the edge of the cortex, in spite of the possibility of some slight damage to the latter by the tar, as it has been found more important, in the case of this disease, to protect the wood from borers than to consider the most rapid method of healing the wound. Where the wounds are large, so that the renewing cortex cannot be expected to grow over them for several years, tarring the exposed wood is absolutely necessary.

Tar or tar mixtures should not be applied over canker patches without previously cutting out the diseased bark, or over patches which have been scraped, or where the disease had not completely penetrated to the wood. In the two latter cases there is always the possibility that some of the diseased tissue has been left. When tar is applied over cankered bark, the disease continues underneath the tar. That fact was well known in the early days of Cacao canker, and it was that which led to the universal condemnation of tar in Ceylon. It was then found that if tar was used the coolies tarred the canker patches without cutting out, or without completely cutting out, the diseased tissue, and the disease continued to flourish underneath the tar. Tar, if applied over cankered bark, may even assist the disease by preventing the drying out which should occur in the dry weather. There would be no objection to the use of tar if one could be certain that all the diseased tissue were cut out, but in the light of previous experience it would appear safer to apply some more fluid liquid, which does not form an opaque waterproof coating, to treated canker patches, and

to reserve tar for subsequent application to the exposed wood.

As previously noted, the disease frequently does not penetrate completely through the cortex, but stops after advancing partly through, and the diseased tissue is then cut off from the surrounding healthy cortex by a layer of cork cells. The patch of diseased bark then dries up, and forms a scale which can be easily detached. Underlying this scale one finds healthy laticiferous cortex. The dry scales do not show any purple colour, as a rule, but are brown internally. They are usually lenticular, and if the fungus has penetrated to the wood in the middle of the patch, they leave a hole extending to the wood when they are removed. This natural healing appears to be due simply to a change in climatic conditions, occurring chiefly in the dry weather. These old scales should be removed, as it has been found that the disease may begin again behind them, especially when it had not penetrated to the wood at the first attack.

As the fungus attacks the fruits and causes fruit rot in wet seasons, the latter then serve as a source of infection and produce spores which convey the disease to the stem. The case is therefore exactly parallel to that of Black Thread, and if the fruits could be removed fewer cases of Claret-coloured Canker would be expected.

That the Claret-coloured Cankers of *Hevea* and Cacao are the same has already been pointed out. In the case of Cacao the fungus is present on the pods practically all the year round, the disease reaching its maximum at the period of the main crop which, in Ceylon, coincides with one of the wettest seasons of the year. Consequently, on a mixed *Hevea* and Cacao estate, the fungus is always present in an active condition, except perhaps for a brief period in the dry season, and capable of furnishing spores which can infect the *Hevea*.

The following instance is cited as an example of the prevalence of the disease on a mixed estate, where the *Hevea* was seven to eight years old, and only the trees which had come into tapping had been examined.

[Table

Field.	Acres.	Number of Trees Tapped.	Number Diseased.	Percentage Diseased.
A	16	1398	94	6·7
B	$12\frac{1}{2}$	802	51	6·3
C	$16\frac{1}{2}$	425	10	2·4
D	$9\frac{1}{2}$	1119	17	1·5
E	6	457	1	0·22

The *Hevea* was planted in some cases 15 feet by 15 feet, and in others 15 feet by 20 feet. Fields A and B also contained old Cacao planted $7\frac{1}{2}$ feet by $7\frac{1}{2}$ feet; fields C and D were similarly interplanted, but the Cacao was young; and field E was interplanted in Tea and surrounded by the Cacao and Rubber fields. The increase in the percentage of diseased trees in the older Cacao blocks is very marked.

The effect of canker on *Hevea* is more serious than on Cacao. In Cacao, although the stem is shaved periodically for canker, the tree continues to yield a crop until it is killed by complete ringing. But as the bark is the source of revenue in *Hevea*, it is impossible to continue cutting it away in the same manner if the cultivation is to be profitable. When the whole of the bark on one side has to be cut away for a length of two or three feet, the tree is useless for tapping for several months, and on old trees the treated area may never be tappable again. Therefore, since periodic treatment of the same tree is out of the question, the measures adopted must, as far as possible, be preventive; and as we know that the Cacao is a permanent source of infection, and that canker is, in general, less prevalent on purely Rubber estates, there is no doubt that the chief preventive measure on a mixed estate must be the removal of the Cacao. When canker regularly attacks *Hevea* which is interplanted among Cacao, the Cacao must be sacrificed if the Rubber is to be maintained as a paying crop.

The Cacao must be uprooted, not merely felled. If the stumps are left in the ground they frequently develop root diseases, sometimes *Fomes lignosus* or *Ustulina*, but more generally Brown Root Disease, which spread from them to the *Hevea* and kill it. This has been proved in many cases where Cacao has been cut out.

The disposal of the Cacao stems and branches is a problem

which does not admit of easy solution. Once the trees are uprooted they are not likely to develop either *Phytophthora* or *Fomes lamaoensis*. But they will certainly develop *Botryodiplodia Theobromae*, which can attack *Hevea* as a wound parasite, and is the serious fungus in "Die-back." It is probable that this might be risked, though the safest plan is to remove and burn the debris as soon as possible.

Black Thread Disease

The renewing bark on the tapped surface of *Hevea*, especially the part most recently tapped, is subject to the attack of several diseases which cause it to decay to a greater or less extent. One of these, or possibly one group of diseases which closely resemble one another, has occurred in all the Rubber-growing countries of the East, and has sometimes caused considerable damage to the renewing bark, and immediate loss of crop owing to the temporary cessation of tapping which it necessitated. It has received several different names in the different countries in which it has appeared, the principal being Black Thread, Black Stripe, Black Line Canker, Bark Rot, Decay of the Renewing Bark, Cambium Rot, and Stripe Canker. The names Black Thread and Black Stripe are perhaps the most appropriate, at least as regards the earlier stages.

In Ceylon a disease of this character was first noticed towards the end of the year 1909, during the North-east Monsoon rains. On the renewing bark just above the tapping cut, the outer layer, which is cut off to form the new cork layer, became depressed in narrow, vertical lines, about half an inch long, and on cutting into these areas a black line was found underneath each one, extending right through the cortex and into the wood. As the disease progressed the outer layer decayed and the black line became evident externally. Subsequently it extended up the tapping surface, and broadened out laterally, so as to form a narrow vertical wound. The lines occurred in varying numbers on the same tapping cut, but all parallel to one another (Fig. 13). If they were distant from one another, narrow vertical wounds resulted, but when they were close together, the adjacent wounds spread laterally

and coalesced, so that in some cases a continuous wound was produced, which extended right across the tapping cut. If tapping was continued, the wounds followed the tapping cut downwards as fresh inner cortical tissues were exposed, and in some cases the lines extended into the untapped cortex below the cut. When the rains ceased the decay stopped. The resulting damage depends on the size of the wounds. The cortex is destroyed down to the wood, and the cambium is killed over the diseased areas. New growth, therefore, can only take place from the edge of

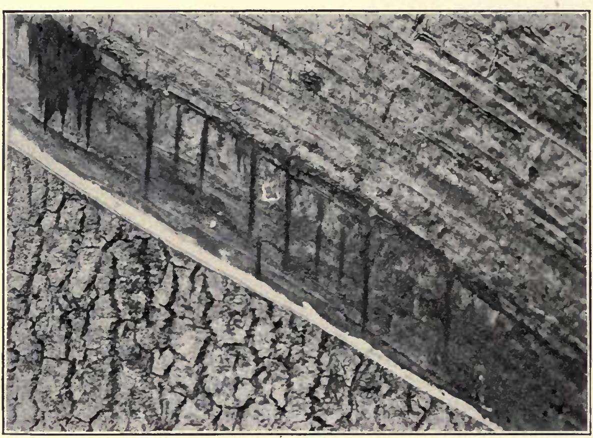


FIG. 13.—Black thread (Ceylon); early stage. Natural size.

the wound, and hence each wound becomes bordered by a swollen callus. In many cases the consequence is a series of narrow parallel wounds which soon heal; but where adjacent lines have coalesced a broad wound is formed which cannot be healed over for some years. It was noticeable, in the earliest cases of this disease, that it was worst on the tapping cuts which were newly opened during the rains of the North-east Monsoon. No organisms capable of reproducing the disease were found in the decaying tissues.

A similar disease occurs in Burma, and has been investigated by Dastur, who describes it as follows. The naked

tissues laid bare by tapping become disfigured by the appearance of vertical, slightly depressed black lines. These follow the tapping cut as it is continued down the stem, and extend in through the cambium into the wood. The blackening of the tissues spreads laterally along the tapped area, and eventually covers the whole cut. Diseased areas soon become vertically cracked, especially during wet conditions, and markedly sunken. From the vertical cracks white latex occasionally exudes, there being, at times, quite a copious flow. In some cases there is a thick pad of rubber between the diseased bark and the wood; in these cases the cambium is completely destroyed and the diseased renewing bark bulges out. This soon decays, leaving a big gaping wound, exposing the wood. The ultimate appearance of the renewing bark is similar to that in the Ceylon disease.

Dastur states that when tapping is stopped the disease stops, and the decay does not extend into the untapped cortex. If new cuts are opened below the old cut, these become diseased as a result of fresh infections.

The Black Thread disease of South India is considered most probably identical with that in Burma, though the description of it differs slightly. It begins as a small dark spot on the inner edge of the tapping cut, and gradually extends laterally and vertically, running upwards in little dark streaks, but seldom over more than a few square inches. The surface of the diseased patch becomes sunken, and the streaks appear as sunken lines. Latex oozes out and coagulates in small masses.

The disease in Borneo appears to resemble that in Burma, as far as particulars are available. The Burma form would appear to differ from that in Ceylon in the exudation of latex, and the formation of rubber pads behind the decayed cortex. The description of the initial stages of the disease as it occurs in Malaya agrees well with what is observed in Ceylon, but rubber pads are said to form when the wound is healing and the callus at the margin is growing over the dead decayed cortex. According to Belgrave and Norris the Malayan form differs from that in all other countries in that its penetration into the wood is much more rapid and deeper, and it extends in the wood both vertically and

horizontally more rapidly than in the cortex. Belgrave states that it may run down past the tapping cut, sometimes for more than a foot into the untapped bark.

Black Thread disease is also found in Sumatra and Java. Rutger's description of it in Java, in his "Heveakanker III.," accords well with the Ceylon form. He states that it forms, immediately above the tapping cut, fine vertical black stripes which extend into the wood. The stripes may broaden out and fuse with one another laterally, so that the whole of the renewing bark may decay. But he adds that the stripes may extend downwards into the bark below the tapping cut and there produce "patch canker." Rutger's previous description, however, differs in describing the initial stage as the appearance of a black round spot on the tapping cut, and the subsequent formation of the black lines above that. This latter description recalls that already quoted from South India.

In all the countries in which a causative agent of Black Thread has been determined, it has been found to be a *Phytophthora*. In Burma and South India it has been definitely established that the *Phytophthora* which causes this disease is the same as the one which is responsible for the fruit disease and leaf-fall. In Malaya, though Black Thread is common, the fruit disease has not yet been recorded. In Java and Sumatra the species of *Phytophthora* which cause Black Thread and fruit disease are again believed to be identical. The probability is that where Black Thread is caused by a *Phytophthora*, the fungus is also capable of attacking the fruits.

The fact that, in most countries, the *Phytophthora* which develops on the fruits, and which subsequently passes over to the leaves and brings about abnormal leaf-fall, is also the cause of Black Thread, furnishes an additional reason for endeavouring to control the fruit disease by cutting off dead branches and removing the green fruits. If the fruits are removed the chief source of Black Thread infection is abolished. During an attack of fruit disease the fungus produces spores in abundance on the diseased fruits, and these, washed down, or splashed on to the tapping cut, set up Black Thread. From South India it is reported that on one estate on which dead branches and green fruits

had been removed over an area of 100 acres as an experiment, Black Thread was much less prevalent on the experimental area than on any other part of the estate, the difference being very great.

Black Thread disease has not been known to kill a tree. When the rains cease the decay stops. In the case of slight attacks the result is a series of narrow vertical wounds, each surrounded by a swollen callus, and though these wounds soon heal over, vertical swollen ridges are left which make the renewed tapping surface uneven. In bad attacks,

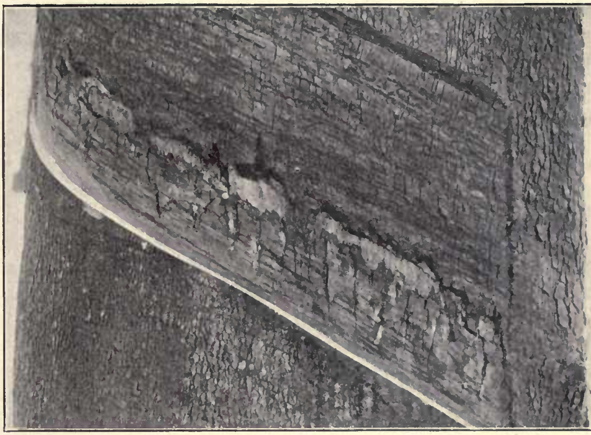


FIG. 14.—Black Thread; an old wound. $\times \frac{1}{6}$.

where the vertical wounds have coalesced laterally, a large open wound extends right across the tapping cut, and this may not heal over for several years. In any case the renewed bark is uneven and irregular, and may not be in a fit condition for retapping at the appointed time.

Black Thread may be combated either by a preventive or a curative treatment. Of the two there appears to be little doubt that *preventive treatment* will ultimately be generally adopted in countries where this disease is prevalent. This consists of painting over the tapping cut with a preservative, or fungicide, after every tapping during the

rainy season. Weak solutions are employed, it having been found that 5 per cent is usually a sufficient strength. Brunolinum, Brunolinum Plantarium, Carbolineum Plantarium, Solignum, Agrisol, and Jodelite have all been found effective. In addition to the above, Jeyes' Fluid is said to have given good results in Java, but it must be used in stronger solution, not less than 10 per cent.

In alternate day tapping, the scrap should be collected on the second day, when the trees are not being tapped, and the solution applied immediately after the scrap has been collected. Daily tapping presents more difficulties, both as regards labour and the actual application, and it may be queried whether it is worth while to try to overcome these in order to maintain that system. Some advocate that in daily tapping the scrap be collected at midday, and the preservative applied then, but the objections to that method are, that the scrap may not then be completely coagulated, or that latex again exudes after the scrap has been removed and makes the application of the preservative difficult and usually imperfect. Others recommend that the preservative be applied at midday without removing the scrap, a method which cannot be carried out properly if the coagulation of the scrap is incomplete.

It has been claimed in the Federated Malay States that the application of Carbolineum or Brunolinum over the scrap has a deleterious effect on the latter, and, to avoid any trouble of that kind, it is recommended that, for daily application, a solution of Formalin and Sodium bisulphite be used instead. This solution is made by dissolving $1\frac{1}{4}$ lbs. of Sodium bisulphite in half a gallon of water and adding one pint of commercial Formalin. That forms the stock solution, which should be kept in a stoppered bottle. For use it is diluted with water to ten times its volume, *i.e.* half a gallon of the mixture to $4\frac{1}{2}$ gallons of water. On the other hand, later experiments are said to have shown that daily painting with 10 per cent Brunolinum does not affect the quality of the scrap. In any case, the question of possible damage to the scrap should not be allowed to prevail against the adoption of proved methods of prevention of the disease.

Tar and tar mixtures have been largely used for the

prevention of Black Thread and other affections of the renewing bark, but they cannot be regarded as equal to Brunolinum, etc., because it is not usually found practicable to apply them after every tapping, for the reasons that they take longer to apply than the more fluid mixtures and, if put on down to the tapping cut, as they ought to be, they clog the tapping knife, lead to an undue consumption of bark, and may contaminate the latex. As a rule, they are applied once a month or once in two months. Hence, during the interval between the applications, the most recently tapped zone is left exposed, and this is the part where infection takes place. In general, therefore, tar mixtures fail to protect the part which needs protection most.

Coal tar has been used in Java, it is said, with very satisfactory results. After experiments carried out for a year no injurious effect was observable on the renewing bark. The renewal was regular and the tarred layer ultimately scaled off, after the formation of a protective brown bark underneath. The renewal was said to be rather better with tar than without. At first the cuts were tarred every other day, but during the rains infection was found to occur in the interval. Tar was then applied every day, and this application was continued throughout the wet season. It is pointed out that it is necessary to train the tappers to tap on the tarred cut, and the tapping should be "light." If not less than a millimetre of cortex is left overlying the cambium, no damage is done. Local gas tar was used.

In Ceylon a mixture of coal tar and tallow has been extensively used, the proportions varying from 40 per cent tar and 60 per cent tallow to 5 per cent tar and 95 per cent tallow, from 10 to 5 per cent tar being the more general. This mixture has been largely replaced by mixtures of coal tar and liquid fuel, in proportions varying from 50 to 10 per cent of coal tar, the latter being the more usual. In these mixtures the depth to which the liquid penetrates the cortex increases as the percentage of tar is increased. On one estate a mixture of 20 per cent coal tar and 80 per cent liquid fuel has been in use for two years, and has been applied twice a week, thus partly overcoming the chief objection noted above. Tar mixtures should not be put on too thick. All that is required is the thinnest possible smear.

Paraffin wax has been used to protect the renewing bark on several estates. This is not easy to work with, as it must be applied in a liquid state, and it rapidly solidifies. To overcome that difficulty, mixtures of wax and oil have been put on the market. In Java a solution of 500 grams paraffin wax and 500 grams resin in one litre of benzene with the addition of 10 per cent Solignum has been tried ; this mixture hardens in a day and gives a transparent film. A solution of equal parts of benzene and resin has also been recommended, and has been favourably reported on, but the high cost of benzene in most countries would prohibit the use of solutions based on it. It has, however, recently been reported that these benzene and spirit solutions have given unfavourable results, and the recommendation of them has been withdrawn.

To cure Black Thread disease the affected tapping surfaces should be painted with a 20 per cent solution of Brunolinum Plantarium, Brunolinum, Carbolineum Plantarium, Solignum, Agrisol, or Jodelite. The mixture should be applied as soon as the disease is observed, and continued every three days for six applications. This treatment arrests the disease and prevents the formation of large wounds. Meanwhile the diseased trees should be rested completely. It is true that if the attack is light latex may be obtained from the sound cortex between the wounds by continuing tapping, but, at the same time, the wounds follow the tapping cut down and cause greater damage. It is also stated that when the attack is a slight one the extension of the wounds downwards can be stopped by tapping less deeply. But, unfortunately, it is not possible to prophesy whether the effect is going to be slight or serious. The general experience is that it is best to rest the trees, and that it seldom pays to open new cuts at a time when Black Thread is prevalent.

The treatment outlined in the foregoing paragraph is one to be adopted when the disease is active, *i.e.* when the patches of diseased cortex are increasing in size. The distinction between active Black Thread, when the fungus is spreading in the cortex and enlarging the decayed area, and old Black Thread, when the disease has stopped and the wounds have begun to heal over, is frequently overlooked. It is a waste of time to begin applying 20 per cent Brunolinum to wounds

which are several months old and are surrounded by a healthy callus. Such wounds should be treated in the usual way for wounds in general, *i.e.* any dead bark scales cleaned off and the exposed wood tarred.

In Ceylon it has not been found necessary to cut out, or scrape off, the decayed cortex. In South India, Malaya, and Borneo it is stated that if that is not done, rubber pads are produced behind the renewing bark and cause it to rot later. The thin layer of dead cortex is said to prevent the ingrowth of the callus at the margin, with the consequence that rupture occurs along the cambium behind the healthy bark, and a cavity is formed which becomes filled with rubber. The statement that rubber pads are formed is doubtless correct, but the suggested explanation does not appear tenable. According to Dastur, the pads form when the disease is active. In such cases they should be cut out.

Care should be taken not to confuse with Black Thread an attack of Claret-coloured Canker on the renewing bark. In the latter, the diseased area spreads uniformly, as a rule, in a continuous patch from the beginning, and equally all over the tapped surface. The diseased bark is usually a yellowish-grey tint internally and does not become claret-coloured, but when it extends into the untapped cortex below the cut, as frequently happens, the typical claret colour is produced. In wet weather a delicate white mould appears on the decayed bark, and in this the *Phytophthora* sporangia may be found, together with other saprophytic fungi. The appearance is quite different from that of Black Thread, though nevertheless the two are frequently confused, or, rather, every disease of the tapped surface is treated as Black Thread. But the two require different treatment. Bark attacked by Claret-coloured Canker must be cut out. The application of 20 per cent Brunolinum often fails to stop the disease, while a covering of tar or wax protects it and prevents it drying up in the dry weather.

There is considerable difference of opinion whether differences in methods or styles of tapping have any influence on the incidence or course of the disease. Theoretically, a flat cut, by allowing moisture to stand on it for a long time, should favour the attack of the fungus, and there is no doubt that in order to increase the possible number of cuts to the

inch, tapping cuts have reached the limit of flatness. There is some evidence that Black Stripe is more prevalent with daily tapping than with alternate day tapping, and it has been stated that it has not occurred on estates tapped every three days.

Close planting, by maintaining a humid atmosphere and excluding sunlight, favours the disease. Thinning out is one of the remedial measures to be adopted on closely-planted estates.

The effect of Black Thread disease extends into the wood, and black lines may be found there running up and down the stem for some distance. All the evidence hitherto available supports the view that it is unnecessary to cut out these lines, or, indeed, to cut out any wood at all. It has not yet been demonstrated that the causal fungus is present in these streaks at any distance above the point where the cortex is decayed. As a general rule, whenever the wood of the stem of a tree is damaged, discoloured lines extend upwards from the damaged region, independent of the presence of any fungus in them, and they are usually caused by poisonous substances which are carried up from the damaged area by the transpiration stream. In course of time the black lines which occur in the wood in cases of Black Thread are buried deeper in the stem by the growth of new wood, and there is no evidence that the disease ever originates again from them.

In certain districts in Ceylon cuts which are opened during the latter half of the year are almost invariably attacked by Black Thread. This may happen, even if the new cuts are opened in September, before the North-east Monsoon rains set in. The reason of this is not apparent. Assuming that the disease is due to a fungus which develops first on the fruits, there will naturally be more of this fungus present after the fruiting season, at least in years when the fruit disease is prevalent. But this does not explain why new tapping surfaces, say an inch broad, are attacked, while the older tapping surfaces are not. To avoid this infection new cuts should not be opened during the last six months of the year. This will upset "change over" tapping systems, in which the change is made every six months, in March and September: but in such cases the tapping must be governed

by the incidence of disease, and the change made once a year only.

The thickness of the cortex left overlying the cambium has perhaps no influence on the incidence of the disease, *i.e.* whether the tapping is deep or shallow the trees are most probably equally liable to attack, but the amount of damage caused may possibly be greater when the tapping is deep. Observations in Java showed that, on 400 trees, where the thickness of cortex left was sometimes less than, and sometimes greater than a millimetre, 90 per cent of the former (194 out of 215) and 67 per cent of the latter (123 out of 185) were attacked, but with very heavy rainfall all the trees became affected.

Leaving the scrap on the tree until the following day is said to have some good effect, both as regards infection and the progress of the disease.

It has frequently been stated that the spread of Black Thread coincides with the direction taken by the tapper when tapping the trees, and consequently that the infection is conveyed from tree to tree by the tapping knife. One would naturally expect that to be the case, especially in countries, or districts, where the fructifications of the fungus develop freely on the diseased bark. But careful observations have not supported the theory. In an experiment on a fairly large scale in Java, no such effect could be detected. It is probable that when the weather conditions are favourable for the development of Black Thread, its spread by other means is so rapid that any effect due to infection by the tapping knife would be masked.

On the supposition that infection is conveyed by the tapping knife, it has been suggested that the tapper should be provided with a solution in which he could dip the knife and sterilise it between tapping one tree and the next. An experiment carried out by Belgrave in the Federated Malay States, showed that if the cuts are painted after every tapping with 5 per cent Izal or the Formalin-bisulphite mixture, disinfection of the tapping knife is unnecessary; and the same is likely to hold good for other disinfectants, such as Carbolineum, Brunolinum, etc. Belgrave has also shown that the mere dipping of the knife in 5 per cent Formalin does not sterilise it.

Pratt has published a series of figures, obtained from an examination of nearly 19,000 trees, which show a continuous and steady decrease in the percentage of trees attacked, as the distance of the current tapping cut from the ground increased. When the tapping cut was from one to five inches from the ground, the percentage of cases was about 30. At six and seven inches the percentages were 27 and 25 respectively. At eight to eleven inches the percentage decreased regularly from 19 to 10, and at twelve to eighteen inches it fell steadily from 9 to a ½ per cent. No cases occurred when the tapping cut was above eighteen inches, according to the table given by Pratt, but he states that on cuts above eighteen inches Black Thread not infrequently established itself, but the attack is usually much less vigorous than on cuts lower down. It is scarcely possible that atmospheric differences can account for the great fall in the percentage of cases between cuts at five and fifteen inches (from 30 to 3·3), and it is probable that some other factor than the height of the cut was operative.

Figures similar to those published by Pratt have also been furnished by Harmsen. When the cuts were below eight inches from the ground, 52 per cent were attacked. At eight to twelve, twelve to sixteen, and sixteen to twenty inches the percentages were about 30 in each case. At twenty to twenty-four inches 14 per cent were affected, and above twenty-four inches only 9 per cent.

Harmsen's figures show that the higher tapping cuts are attacked, though the percentage is smaller. It might be suggested that the length of time a surface has been tapped may be a contributing factor in these results, but that does not agree with the observed facts. In the first cases of Black Thread recorded in Ceylon the cuts were at a height of four feet, and only an inch or so of bark had been removed.

The Fungi

Though it has been considered convenient to discuss the various *Phytophthora* diseases together, and the development and progress of these diseases on the different parts of the tree—fruit, leaf, and stem—are similar in all cases, the species of *Phytophthora* which cause them are not, as far as the

evidence at present available shows, the same in all the countries in which these diseases occur. The question of the identity of the different species is not yet completely settled, and the following summary must be regarded merely as representing the facts which have been considered established by various investigators.

In Ceylon it was demonstrated in 1910, by inoculations on *Hevea* with the *Phytophthora* from Cacao, that the Claret-coloured Cankers of *Hevea* and Cacao were caused by the same fungus, viz. *Phytophthora Faberi*. The *Phytophthora* which was first found, and which the more generally occurs on the fruits and leaves, is also *Phytophthora Faberi*. Recently, *Phytophthora Meadii*, the South Indian species, has been found on *Hevea* fruits, leaves, and branches in Ceylon, but it has not yet been obtained from the Black Thread. There are thus two species of *Phytophthora* on *Hevea* in Ceylon.

In Java Rutgers has carried out an extensive series of cross infections with different species of *Phytophthora* which occur in that country and in Europe, and finds that the *Phytophthora* on *Hevea* is identical with that on Cacao, viz. *Phytophthora Faberi*. This species occurs also on Nutmeg, but is different from the Phytophthoras on Tobacco, *Colocasia*, and *Jatropha Curcas*. The strain of *Phytophthora Faberi* on *Hevea* and Cacao is more virulent for those trees than for Nutmeg, while the one on Nutmeg is more virulent for Nutmeg than for Cacao or *Hevea*. As a result of his infections, Rutgers holds that Claret-coloured Canker, fruit rot, and Black Thread in Java are all caused by the same species, viz. *Phytophthora Faberi*.

Dastur investigated Black Thread and fruit rot in Burma, and found that both these were caused in that country by the same species of *Phytophthora*, which, however, was not *Phytophthora Faberi*. As a result of his experiments, Dastur decided that the Burma species was only a wound parasite on the stem, *i.e.* it could not attack the stems unless they had been previously wounded, and that it could not attack Cacao.

McRae, who has made a thorough examination of the *Phytophthora* diseases of *Hevea* in Southern India, finds that the *Phytophthora* which occurs on *Hevea* there is probably the same as that in Burma, and has named it *Phytophthora Meadii*. It causes fruit rot, leaf-fall, die-back, and Black Thread, but

apparently not the Claret-coloured Canker. McRae has also found that *Phytophthora Meadii* can attack Cacao fruits, but to a limited extent.

In the Federated Malay States Black Thread is caused by a *Phytophthora* which is considered identical with the Burma species, but no fruit disease has yet been observed.

The evidence indicates that there are two species of *Phytophthora* which can attack both *Hevea* and Cacao, viz. *Phytophthora Meadii* and *Phytophthora Faberi*; and that, in the case of *Hevea*, the former causes fruit rot, leaf-fall, and Black Thread, while the latter causes fruit rot, leaf-fall, and Claret-coloured Canker. On the fruits *Phytophthora Faberi* usually forms a continuous white covering, while *Phytophthora Meadii* may at first form small isolated white tufts; the differences between the appearance of the diseased fruits in the two cases will be evident from the descriptions on page 103, where the first relates to *Phytophthora Faberi* and the second to *Phytophthora Meadii*.

The most important difference, from the economic standpoint, between the two species lies in the effect of the fungus on the general condition of the tree. When trees suffer from the leaf-fall and pod disease caused by *Phytophthora Faberi*, the yield of latex is not notably affected; but when they are similarly attacked by *Phytophthora Meadii*, the yield falls off enormously and it may not be worth while to tap.

SUMMARY

PHYTOPHTHORA DISEASES

Abnormal Leaf-fall and Fruit Disease

Identification.—Outer wall of the fruit becomes dirty watery green, finally blackish, sodden, and soft. The fruits do not dehisce, but remain hanging on the tree. Soon afterwards the leaves begin to fall, and subsequently some of the green twigs die back.

Occurrence.—Usually during prolonged wet weather when the fruits are ripening. In Ceylon and South India during the South-west Monsoon.

Treatment.—Remove all rotten fruits and dead branches after wintering and before the monsoon rains begin.

Claret-coloured Canker

(*Phytophthora Faberi*, Maubl.)

Identification. — No marked external indications; sometimes a slight exudation of a rusty-coloured liquid. The layer beneath the outer brown bark is black, and internally the cortex is discoloured, at first yellowish-grey, then claret-coloured, like the inside of the fruit-wall of a ripe mangosteen. The discoloured area is surrounded by a black line (Plate IV., Fig. 12).

Occurrence.—Attacks trees of all ages, but more usually from four years upwards. Frequently occurs on the renewing bark above the tapping cut, and may be mistaken for Black Thread, from which it differs in its occurrence, from the beginning, in a continuous patch, not in separate parallel lines, and in its colour. In recently-tapped bark the claret colour may not be developed, the diseased bark remaining yellowish-grey.

Treatment.—Excise all discoloured bark, and paint the wound with 20 per cent Brunolinum, etc. Tar wounds which extend to the wood.

Black Thread

Identification.—Begins as a series of narrow, vertical, black lines, parallel to one another, just above the tapping cut. These may broaden out laterally and coalesce, forming a continuous wound parallel to the tapping cut. The black lines extend into the wood (Figs. 13 and 14).

Occurrence.—Occurs during wet weather, particularly on recently-opened tapping cuts. In Ceylon especially attacks cuts opened in the latter half of the year.

Treatment.—To prevent Black Thread paint the tapping cut after every tapping during the wet weather with a 5 per cent solution of Brunolinum, Brunolinum Plantarium, Carbolineum Plantarium, Agrisol, Solignum, or Jodelite.

To cure cases of Black Thread paint the affected tapping cuts with a 20 per cent solution of one of the above-named liquids every three days for six applications, resting the trees meanwhile.

Where rubber pads have formed these should be cut out. It is not necessary to cut out the wood.

CHAPTER V

STEM DISEASES

Of the stem diseases of *Hevea* the most important are those which attack the lower part of the stem, on the area usually tapped. The oldest known of these is Claret-coloured Canker, which first appeared in Ceylon about 1903. To this must now be added Black Thread and Mouldy Rot, which attack the tapped cortex, and Brown Bast, which attacks chiefly the untapped cortex of trees in tapping. There is sometimes a tendency to minimise the seriousness of Brown Bast on the ground that it has never been known to cause the death of a tree, but if it renders a tree untappable, it is, from the economic standpoint, just as serious as if it killed it.

Claret-coloured Canker and Black Thread have been described in the chapter on *Phytophthora* diseases. The present chapter deals more especially with those diseases which attack the upper parts of the stem or branches. Of the latter, Pink Disease and Die-back are still the only diseases of importance. Brown Bast is described in the chapter on non-parasitic diseases.

Pink Disease

(*Corticium salmonicolor*, B. and Br.)

This disease was discovered by Zimmermann in Java, where it attacks cultivated plants of all kinds, and is apparently more serious than in other countries. He published a description of the fungus under the name *Corticium javanicum*. In 1904 the discovery of a pink fungus on *Hevea* bark was announced in the Federated Malay States, but the species was misidentified as *Corticium calceum*. In 1906 it was found to attack *Hevea* in Ceylon and was recorded

under the name of *Corticium javanicum*; and shortly afterwards it was found to occur in South India. In 1909 it was again recorded from the Federated Malay States, this time under the name of *Corticium Zimmermanni.* In the West Indies a pink fungus which attacks Cacao was referred to *Corticium lilacino-fuscum*, but it has been determined by Miss Wakefield that the West Indian species is the same as the common parasitic *Corticium* of the Eastern Tropics. As stated by me in 1911, the proper name of the fungus is *Corticium salmonicolor*, that name having been given to specimens sent from Ceylon by Thwaites about the year 1870.

Pink disease, therefore, occurs all round the Tropics. In Ceylon it attacks *Hevea*, Tea, Cinchona, Camphor, Orange, and many ornamental shrubs and trees. In Java, where it is known as Djamoer oepas, 141 different species of plants are known to be attacked by it, the list including Coffee, Ramie, Cacao, Cinchona, Nutmeg, Tea, Kapok, Pepper, Coca, Cinnamon, Kola, *Castilloa elastica*, *Hevea*, Dadap, *Grevillea*, Anatto, Mango, and many other trees and shrubs of minor importance. Ridley stated that it occurred in the Straits Settlements on Ramie and *Strobilanthes*, when overcrowded and too damp. In the Federated Malay States Brooks and Sharples have recorded its occurrence on *Hevea*, Cacao, Coffee, Camphor, Lime, Durian, Jak, and other species. In South India it attacked *Crotalaria* interplanted among *Hevea* in districts where the former had grown to a great height and had developed stems up to an inch in diameter. It is frequently found on fruit trees of all kinds, and appears to show a preference for such, but it will apparently attack any plant which has a woody stem. It has not, however, been found to attack monocotyledons, *e.g.* palms, Sugar-cane, etc.

In *Hevea* the disease appears generally to originate at the fork of a tree, or where several branches arise at the same level from the main stem. The first sign observed is usually the appearance of a pink incrustation of interwoven hyphae over the bark. This pink patch gradually extends, and may ultimately cover the whole circumference of the stem and the bases of the adjacent branches for a length of several feet. Under the central part of the patch, the bark has usually been killed by the fungus and is brown and dry, but towards the margin it may still be alive and laticiferous.

This is explained by the fact that when once the fungus is established it travels over the bark more rapidly than within it; hence, although the whole of the bark is permeated by the fungus over the greater part of the patch, the advancing margin is generally superficial. The dead bark usually dries up and cracks and splits away from the wood. The fungus penetrates the wood, but the fructification does not appear to be formed except on the bark.

The pink patch is extremely thin, and when old splits everywhere in lines, more or less at right angles to one another (Plate V., Fig. 1). Old specimens lose their pink colour and become ochraceous, or, when very old, are bleached to white. In very wet weather, even young, recently-developed patches may be white, and the patches which are then bearing spores appear waxy, and sometimes pinkish-ochraceous.

The appearance described above is that of the typical form of the fungus, and when this pink incrustation is present the disease is unmistakable. There are, however, three other forms in which the fungus may appear on *Hevea*:

(1) A thin shining layer of long silky hyphae which sometimes scarcely hides the underlying bark. The hyphae run more or less longitudinally along the stem, and sometimes form very fine strands, which are united laterally by finer threads (Plate V., Fig. 2). They differ from the Thread Blights in being less conspicuous and more generally spread over the stem. This form frequently occurs at the margin of a pink patch in wet weather when it is spreading rapidly, and the pink incrustation develops over it subsequently.

(2) Minute pink pustules, situated in small cracks in the bark, arranged more or less in lines along the stem (Plate V., Fig. 2). These are sometimes found on branches which also bear the pink incrustation, but they may occur on branches which do not show any other sign of Pink Disease. In wet weather these pustules often appear white.

(3) Orange-red pustules, about one-eighth of an inch in diameter. These are embedded in the cortex, which is radially cracked round each. They consist of masses of spores, which are formed within the cortex, and raise and crack it. This form was formerly described as *Necator decretus*, but Rant has shown that it is a stage of *Corticium salmonicolor*. This stage appears to be rare in Ceylon, but

frequent in Malaya and Java. Brooks and Sharples state that, in their experience, the *Necator* stage has been confined to the side of the branch which is exposed to the brighter light. Rant states that on *Cinchona* the pustules are superficial, as well as embedded in the cortex; and that on lateral branches the *Necator* stage occurs on the upper side, and the *Corticium* stage on the lower.

Any two or more of the four stages can occur together on the same branch.

The spread of the fungus on the individual tree is largely governed by the conditions of moisture or exposure; if, for example, the rain-water runs down one side of a tree only, the fungus may be confined to that side; similarly it will exhibit greater growth on the more shaded side. The amount of damage done before the disease is noticed depends upon the size of the tree. Young stems about two years old are quickly encircled and ringed, but on old trees the pink patch should be detected before it has grown completely round the tree. When the tree is ringed, all the parts above the injury die.

During the monsoon rains the fungus, if not attended to, grows continuously and kills off the bark uniformly. The side branches at the point of attack are ringed, and thus killed, and the bark of the main stem falls off in large patches. Between the dead bark and the wood, insects of various kinds are found, but these have merely taken refuge under the loose bark, and are not responsible for any of the damage. Frequently streams of latex issue as the fungus penetrates the cortex and reaches the laticiferous tissue. Young trees may be ringed, and the whole of the tree above the point of injury die, in a single rainy season.

In many cases, however, in countries which have distinct wet and dry seasons, the disease has not advanced far enough to kill the top of the tree by the time the rains cease. The fungus then stops growing when the dry weather sets in, after having killed off part of the cortex and cambium on one side of the main stem, and perhaps some of the side branches in addition. This leaves an open wound over which there is no cambium to produce new wood and cortex. Consequently there is formed a "canker," *i.e.* an open wound surrounded by a swollen callus. Large open wounds on the upper part

of the stem are often the result of the attacks of Pink Disease.

In the majority of cases the pink incrustation is always present, and there is no difficulty in diagnosing the disease. Where the growth of the fungus has been checked by the dry weather and a canker formed, the incrustation may have weathered off, or have been thrown off with the dead bark; but it is usually possible, even in such cases, to find traces of the pink patch on the scales of dead bark which persist round the wound.

The disease is conveyed from tree to tree by spores which are blown by the wind. Judging from the time of attack, it is most probable that the fungus develops in the jungle on native shrubs or trees at the beginning of the monsoon, and then produces spores which blow into the neighbouring plantations. For example, on one Ceylon tea estate, bordered by jungle, the attack always begins towards the close of the monsoon. In dry weather the fungus probably survives in a vegetative state, *i.e.* as mycelium in the plant; it is scarcely probable that the thin-walled spores would survive the dry season. The disease begins in the fork of a tree, or where several branches arise more or less in a whorl from the main stem, because such places are kept damp by the rain water which flows over them, and afford favourable conditions for the germination of the spores. When the spores germinate they give rise to a mycelium, which apparently behaves differently under different conditions. In some cases it first of all forms a superficial patch and penetrates into the cortex later. In other cases it appears to penetrate into the cortex immediately, and for some time to grow inside it, appearing later in the form of minute cushions of pink tissue in cracks in the bark. Ultimately a continuous pink incrustation is formed in either case.

The pink patch, which is at first composed of interwoven hyphae adpressed to the bark, develops short cylindrical cells (basidia) perpendicular to the basal hyphae, and each of these basidia bears four minute spores at its apex. The spores are thus produced on the surface of the pink patch, ready to be blown elsewhere at the first opportunity. There is, in addition, the other kind of spore which is produced in the *Necator* pustules; these spore masses are waxy,

and the spores are only likely to be distributed in wet weather when they are separated by the rain. Brooks and Sharples state that the *Necator* form is found more frequently in Malaya than the basidial form, most of the pink patches being sterile, and it is likely that it takes the more active part in the dissemination of the disease in that country.

Pink Disease may be expected to be the more prevalent under conditions of high humidity, as in countries with a high rainfall, or among closely-planted Rubber. It is only sporadic in Ceylon, where a distinct dry season prevails, and it appears to be rare on *Hevea*, now that the majority of estates have been thinned out. But it is not necessarily confined to damp localities, and it occurs fairly frequently on isolated trees standing in open situations.

Though Pink Disease is easily distinguished, several other things have from time to time been mistaken for it. One of these is the orange, or reddish, alga which forms large patches on smooth-barked trees in the Tropics. Another is the pink mould, *Monilia carbonaria*, which nearly always appears on half-burnt sticks, and seems to consist of nothing but a powdery mass of spores. Yet another is a fungus, *Patellea rosea*, which is often found on dead *Hevea* bark, in the form of flat, circular, or oval, pink patches, only a few millimetres in diameter, smooth and firm, with a narrow white margin. All these are quite harmless.

When Pink Disease attacks young trees, one to two years old, they should be cut back below the affected part. The treatment of older trees must depend on the extent to which the tree is attacked; in many cases it will be possible to cut away the diseased bark only, if it is discovered before the fungus has grown completely round the tree, but if the injury is extensive the diseased stem must be cut off in these cases also. If the top of the tree is dead it should of course be cut off well below the dead part. All infected branches, etc., must be burnt. Wounds caused by excising the diseased bark or pruning off the affected stem should be tarred; but in spite of the tarring it is frequently found that the pollarded stem rots back and the tree is ultimately lost, because *Hevea* wood is not hard, and it is difficult to protect adequately a large, exposed, more or less horizontal surface. Hence the cut on the main stem should be made

with a slope of about 45°, and it might with advantage be protected by cement or tin.

Old wounds of Pink Disease, where the fungus has ceased to grow, at least temporarily, should be tarred, and the tarring should extend over the surrounding bark so as to kill any superficial mycelium which may be persisting round the wound.

In 1909 Pink Disease caused much loss on many estates in South India by killing large numbers of young trees; and in the following year an application of Bordeaux Mixture was made, just before the monsoon set in, in order to prevent infection during the ensuing wet weather. The mixture was applied with a brush, and painted on where the branches joined the main stem. On one estate the cost of treating 500 acres was Rs. 150.00, but 200 acres bore only young trees, two and a half years old, and cost very little. It was stated that the treatment was completely successful, and that the cases of attack had been reduced to a few individual instances, and these were probably due to the careless application of the Bordeaux mixture. Thus, in one instance, out of 60,000 treated trees there were only three cases of Pink Disease, where formerly there would have been hundreds. On estates where Bordeaux mixture had not been used the disease had been as bad as usual, and the affected trees were about 1 per cent.

It is probable that the foregoing method would give favourable results where it is practicable, *i.e.* in the case of young trees, or where the disease reappears periodically on small areas. In Ceylon this disease is not, as a rule, spread over the whole estate, but occurs in certain patches. If the trees on fields which are known to be liable to infection were treated in the manner described prior to the rains, loss would be prevented. While the disease does not cause any widespread damage in Ceylon, the trees attacked are usually over six years old, and it is worth while making some attempt to save them. But in countries where Pink Disease on *Hevea* is really serious, it is agreed that painting with Bordeaux mixture is impracticable.

In the Federated Malay States, where in certain districts Pink Disease attacks a large number of trees, two methods of treatment are in vogue, viz. tarring and pruning. There

is considerable difference of opinion as to the relative merits of the two systems. On the one hand, it is held that cutting out and burning all infected material is the only safe course, while on the other it is maintained that tarring the diseased parts is quite effective and very little cutting is necessary. A combination of the two systems would appear to be the better course, and the following method has been recommended.

When the disease appears for the first time on an estate, and only a few trees are attacked, all diseased branches and stems should be drastically pruned off and burnt. Even in such cases it is advisable first of all to paint the diseased areas which bear the fungus with tar, or a mixture of tar and liquid fuel (crude oil) in the proportion of six parts of tar to four of liquid fuel, in order to minimise the risk of spreading the disease by scattering the spores, and to render harmless any pieces of infected bark which may fly off when the branches are cut. The tar will also assist in thoroughly scorching the bark when the branches are burnt. All diseased material must be burnt as soon as possible. The foregoing method is recommended for (1) fields not in bearing, (2) where the trees have not been thinned below one hundred to the acre, and (3) where the infection does not exceed ten trees per acre.

Where the number of trees is below a hundred to the acre, or where more than ten trees per acre are attacked, the following modification is recommended. All dead branches, and all affected branches not thicker than a man's arm, should be tarred, cut off, and burnt, as in the previous cases. On the thicker branches and the main stem the infected parts should be painted with the tar and crude oil mixture, taking care to cover thoroughly not only the diseased parts, but a length of stem one foot above and one foot below the apparent limit of the disease. The mixture must be well rubbed into all cracks in the bark, particularly at the forks. At the end of a fortnight the trees should be re-examined, and if it appears that the fungus is still growing, a second application of the mixture should be given.

If the fungus does not seem to be growing at the time of the second examination, the tree should be examined again later. Periodic observations are essential, and when the

fungus appears for the second time, a second application of tar and liquid fuel must be given. But if two applications of the mixture fail to stop the growth of the fungus, the infected parts should be cut off and burnt.

Failure in treating Pink Disease is attributable to (1) insufficient cutting of diseased branches, either through tarring branches which ought to have been cut off, or through not cutting them off far enough below the part infected; (2) bad tarring, the area tarred being too small, or no second examination being made; (3) insufficient number of coolies in the pest gang, so that the whole estate cannot be inspected within a fortnight or three weeks as it should be; (4) discontinuance of treatment in dry weather; (5) failure to burn infected material.

Diseased material should be burnt, or disposed of, on the day it is cut. It is often difficult to burn fresh material in wet weather, but it can be at least partly burnt and well scorched outside, and even that will minimise the risk of infection. It has been suggested that the infected material should be placed in lime pits in wet weather.

Ustulina zonata, Lév.

Ustulina zonata is best known as the cause of a root disease of *Hevea*, and its effect in that character is described in the chapter on root diseases. But it can also attack the stem at a considerable height above the ground, independently of any disease on the roots.

In the earliest cases discovered of *Ustulina* as a stem disease, the fungus attacked the stem at a fork. These were without doubt due to spore infections, the wind-borne spores lodging in the broken and rotten bark scales at the forks, and producing a mycelium which penetrated into the wood. Frequently only one limb is affected, the bark becoming rotten in a long triangular area along the upper side of the branch, and the wood beneath it decayed. Rain water soaks into the decayed wood and renders it soft, and a cavity may ultimately be formed. Sometimes a similar decayed area runs down the stem from the fork. Latex frequently exudes from the sound tissue round the wound, and runs down the stem in streaks which, as usual, soon

turn black. The fructifications of the fungus are produced on the decayed bark (Fig. 15), and cases have been observed where they were present on the stem in a continuous sheet below a fork for a length of about eighteen inches. As a rule, trees affected in this way break off in a moderate wind, sometimes the whole of the top of the tree falling over, but more usually only one of the limbs of the fork. In the latter case the remaining half is usually decayed and partly hollowed out at the point of fracture, and its fall is only a question of time.

In the Federated Malay States it is recorded that *Ustulina* enters the stem through the shattered ends of large branches which have been broken off by some means or other. Such broken ends should be cut off flush with the stem, and the exposed wood tarred.

FIG. 15.—*Ustulina zonata*; fructification on *Hevea* stem. × ½.

Whenever the stem of the Rubber tree has been damaged it is liable to be attacked by *Ustulina*, but it is very noticeable, at least in Ceylon, that such attacks usually occur on diseased or damaged areas on which the previously affected bark has remained more or less *in situ*, *i.e.* has not fallen off and exposed the wood. For example, in the case of Claret-coloured Canker the disease may stop after extending to the wood over a large area, and the dead bark may remain adhering to the stem. If these wounds are not cleaned up they are frequently attacked by *Ustulina*. On a properly conducted estate this, of course, does not happen, but it is by no means uncommon to find extensive developments of the fructifications of *Ustulina* on neglected canker patches

on small native holdings. The fungus works into the wood and kills the tree by destroying the wood right across the stem, but before that happens there may be a large cavity formed, extending from the originally diseased side deep into the wood. The diseased wood is permeated by black lines.

Attacks of *Ustulina* also occur commonly on trees which have been scorched. Here, again, the damaged bark frequently remains *in situ* for a long time. Such trees are quickly attacked by boring beetles, and Sharples considers that the fungus follows the beetles, and that its spores may be introduced by them into the tree.

The fructification of *Ustulina zonata* has been described in the chapter on root diseases. Another fungus of an allied genus also occurs frequently on old canker wounds and on scorched trees, and apparently produces the same effect as *Ustulina*. Its fructification appears first as a cluster of more or less erect white stalks, branched like stag's horns towards the tips, and up to an inch in length. These are white at first, but subsequently darken from the base upwards. The apex of each stalk swells out laterally, and the separate swellings fuse together, so that a continuous cushion, with a surface composed of small polygonal areas, is formed (Fig. 16). These cushions may be up to four inches in diameter, and half an inch thick in the middle. They are greyish-white at first, but become black when old. Each polygonal area bears numerous black dots, and in many cases a central conical point. This latter feature depends upon the position of the swelling on the original stalk; if the apex expands, there is no central point on the perfect fructification, but if the swelling begins below the apex, the latter persists as a conical point. When the fungus is prised off the bark, its lower surface is seen to consist of a number of the stalks, black, interlacing, and fused together. This fungus is *Kretzschmaria micropus*. It is a wound parasite on *Hevea* under the conditions stated above. The wood attacked by it is permeated with black sheets, and shows black lines and ovals on a section, exactly like those of *Ustulina* in general shape, but usually somewhat thinner.

Old canker wounds should be cleaned of all dead bark

scales and tarred, and scorched trees should be treated as early as possible.

When a tree is attacked by *Ustulina* at a fork, it is seldom possible to do more than pollard the tree below the diseased part. There may be instances where, when one limb has broken off, the decayed tissue may be cut away from the other and the wound tarred, but, in general, the remaining limb is so weakened that it soon falls. Where this mode of attack of *Ustulina* is prevalent the main forks of the trees

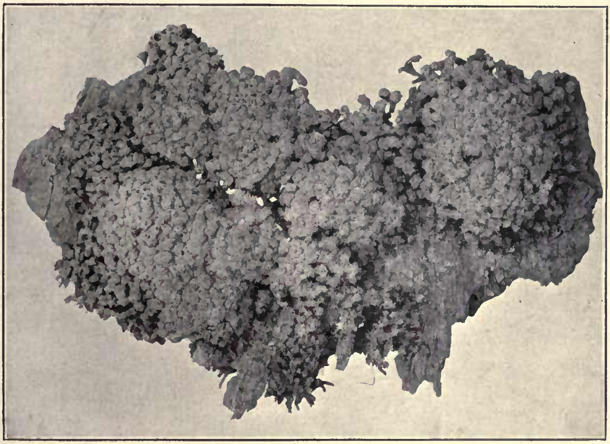


FIG. 16.—*Kretzschmaria* ; fructification. Natural size.

should be cleared of all loose bark, and painted with coal tar, or a mixture of tar and tallow. The latter mixture lasts longer than pure coal tar, but if the cost is high, renewed applications of tar every six or nine months might be cheaper.

Death of Green Twigs

The young green twigs of *Hevea* may die off from several causes, either from the direct attack of a fungus on them, or through the indirect effect of a disease in some other part of the tree, or from environmental conditions which interfere with the normal relations of the water supply and the plant.

L

Wind may kill off the young twigs, especially at high elevations on hill-sides exposed to the full force of the monsoon.

The effect of a root disease is often manifested by the death of the green twigs, usually all over the crown. This is an indication of root disease which is often of assistance in detecting cases in an early stage round a known root-disease patch. But when this appearance is general over a large number of trees, it is improbable that root disease is the cause.

Any injury to the roots is liable to diminish the supply of water to the crown, and consequently to bring about the death of the twigs. This effect has been known to follow frequent forking, especially in the case of poorly-grown trees on gravelly or cabooky soil. Forking must break a large number of the smaller roots, and if repeated at too close intervals may result in a set-back to the trees.

In the early days of Rubber cultivation, death of the young twigs sometimes ensued after the trees had been tapped by the drastic methods then practised, especially when all the cortex on the lowest six feet of the stem was tapped in one year, and wounds down to the wood were frequent. But it is scarcely probable that this consequence will follow the present methods of tapping.

Death of young twigs, as already noted, follows an attack of the *Phytophthora* pod disease and leaf-fall. In this case the fungus may travel from the diseased pod to the twig through the stalk of the pod, and attack the twig near its base, so that the upper part dies from lack of water, or it may attack the green stem directly.

In addition to the foregoing causes, the green twigs may be killed by the direct attack of a fungus on them. Two fungi are known to act in that way, and others are under suspicion. The two in question are *Gloeosporium alborubrum* and *Phyllosticta ramicola*. Their effects are so similar that they may conveniently be considered together. Indeed it is not uncommon to find both fungi on the same dying twig.

Phyllosticta ramicola and *Gloeosporium alborubrum* usually attack a twig about the middle of its length. They do not, as a rule, begin at the apex of the twig and work down to the base. Experience in the Federated Malay States agrees with

that in Ceylon; in the former country the *Phyllosticta* is said to attack the twig about six to eighteen inches below the apex. *Gloeosporium* occurs more frequently on the young twigs soon after wintering, and often causes a fall of leaf, but either can occur throughout the year. Infection frequently takes place at the point where a leaf joins the stem, perhaps because water may lodge in the angle between the two, so that the spore finds suitable conditions for germination there. The affected part turns dark brown, and this discoloration extends up and down the shoot, while the leaves fall as the fungus advances past the base of the leaf-stalk. After a time the diseased length turns grey in the centre (Plate III., Fig. 1). The colours assumed by the dead shoots are not distinctive; any dead *Hevea* shoot will turn grey; but the progress of the discoloration from the middle of the shoot is typical of an attack of one of these fungi. Consequently, in order to arrive at a correct diagnosis, the shoots must be examined before they have died completely.

The fructifications of these fungi are formed beneath the epidermis of the twig on the grey region. Those of the *Phyllosticta* are very minute, and scarcely visible to the naked eye, but they may be detected on careful examination by the elevations of the epidermis over each one, which make the twigs rough; each fructification is a small, black case (pycnidium), containing minute, hyaline spores. The fructifications of the *Gloeosporium* are more conspicuous, because the spores are extruded through the broken epidermis in pink, or sometimes white, masses, especially in wet weather: these masses can be seen with a hand lens.

These two diseases are most often observed on young trees up to two years old, when large numbers may have the leading shoot killed back by them. But they also occur quite frequently on older trees. On young trees the dead leader may be pruned back, but it is not practicable to do anything when larger trees are attacked. Neither of these fungi is in itself serious. Dead twigs killed by them are quite common, but in the majority of cases nothing further happens. The danger lies in the fact that the dead shoots may afford a point of entrance for the Die-back fungus, *Botryodiplodia*, and therefore they should be removed where practicable, *i.e.* on young trees.

Both the *Phyllosticta* and the *Gloeosporium* occur in Malaya, Java, and Ceylon.

Die-back

(*Botryodiplodia Theobromae*, Pat.)

The name " Die-back " is applied to a disease of *Hevea* which, in its most general form, exhibits well-marked characteristics. The tree begins to die back from the top, and the disease progresses rapidly down the main stem, killing off the whorls of branches in succession as it reaches them, the lower parts meanwhile being quite healthy and full of foliage. Thus, if a tree has four whorls of branches, the death of the leading shoot is followed, after a short interval, by that of the uppermost whorl of branches, the three lower remaining normal. Then the second whorl dies, while the lower two are still unaffected, and this process continues until all the branches are killed, and the trunk is dead down to the roots.

The progress of the disease is usually very rapid. In some instances the tree is dead within a month or six weeks after the death of the uppermost branches. In Malaya, it has been recorded that a two and a half year old tree was killed back to four inches from the ground within twelve days.

The trees are generally attacked in groups, sometimes of about a dozen: one or two of these are usually killed, but the others are generally in earlier stages of the disease and can be saved by pruning off the dead tops. Richards records that, in one instance in Malaya, 150 trees, seven years old, were affected in one group: not more than six of these were killed, but many had to be cut back below the fork.

In the typical case described above, the fungus, *Botryodiplodia Theobromae*, enters the stem at the top through a dead green shoot. The shoot may have died from one of many causes, but, in general, the fungus appears to enter through shoots which have been killed by *Gloeosporium alborubrum* or *Phyllosticta ramicola*. The fungus then grows down the stem, both in the wood and the bark, but rather more rapidly in the former; and as it descends to the level of the branches it kills them, either by attacking them or by cutting off their

supply of water. The wood is blackened, and the cambium, with the innermost layers of the cortex, becomes a black film on the surface of the wood. In the early stages these layers are converted into a black, or dark brown, slimy layer, but this subsequently dries, and the dead bark often cracks and falls off.

The blackening of the wood is due to the presence of the mycelium of the fungus in the tissues, this mycelium when mature varying with age from smoky grey to dark brown. But the youngest parts of the mycelium are not coloured, and hence the discoloured wood does not indicate the full extent of the region invaded by the fungus. The mycelium may extend in the wood from four to six inches beyond the part which is evidently dead.

Practically the only other stem disease at present known whose effect could be confused with that of "Die-back" is the Pink Disease caused by *Corticium salmonicolor*. In cases of the latter disease, the whole of the branches above the point attacked may die off, leaving the lower branches still healthy; but this disease is easily distinguished by the pink sheet of fungus tissue on the stem, usually at a fork or where several branches arise close together.

In addition to the mode of attack described above, *Botryodiplodia* may similarly begin on the terminal shoot of a large lateral branch, and advance along the branch to the main stem, or it may attack the main stem directly through a stub which has been left by pruning off a branch in the wrong way. In either of these cases the result may be the same as in the more usual method of attack, *i.e.* the fungus may grow completely across the stem, cutting off the water supply from the upper parts and causing them to die, and at the same time it may travel down the stem equally and kill it uniformly down to the base. But in some instances its effect is more limited, and it only travels up and down the stem in a long strip above and below the point of entry. The wood behind this strip is discoloured, as before, and the discoloured region often extends like a wedge towards the centre of the tree. In the early stages of such an attack, the discoloration is often confined to the cambium for a considerable distance.

The fructification of the fungus is formed in the dead

bark. It is a small black sphere, about one-hundredth of an inch in diameter, filled with spores. These spores appear white when immature, and if the bark is shaved carefully and the spheres cut across, they consequently appear as black circles with a white centre. The spheres frequently occur close together, and united into a continuous mass; this happens especially when they develop in cracks in the bark, and in such cases they may form a black projecting cushion. The spores are extruded from the spheres when ripe, and cover the surface with a fine black powder like soot. In dry situations this powder may be white at first and turn black later. When examined under a microscope the spore is seen to be oval with a transverse wall across the middle.

When trees are attacked by Die-back, their tops must be cut off about a foot below the dead part and burnt. If the diseased stems are left lying about the estate, they will hatch out myriads of spores, all ready to attack other trees when they get an opportunity. *Botryodiplodia Theobromae* is an extremely widespread fungus, and it would be quite impossible to eradicate it, but there is no need to encourage it by neglecting to remove the dead stems. It grows excellently on all dead stems of *Hevea*, no matter what the cause of death, and any one can obtain specimens of the fungus by cutting down a healthy tree and leaving the stem on his verandah for about a fortnight. Fortunately, the fungus is not a direct parasite of *Hevea*, but can only attack it through wounds or dead branches.

If the disease is confined to a narrow strip down one side, the affected cortex should be cut out and the wound tarred. Diseased wood may be cut out if it does not extend very deep, but it is not worth while to hollow out a tree.

Botryodiplodia Theobromae has long been known as a parasite of Cacao, and it has been proved by several investigators that, on that plant, it is only a wound parasite; it does not attack the stems or pods unless they have been previously injured, or attacked by other fungi. The case with regard to *Hevea* is exactly similar. Moreover, even as a wound parasite it appears to be selective. For example, it develops on *Hevea* pods killed by *Phytophthora*, or on cankered *Hevea* bark; but it does not, as far as has been

observed, attack the cortex exposed in tapping, nor the wood laid bare by tapping injuries.

Die-back of *Hevea*, as a result of the attack of *Botryodiplodia*, is known to occur in Ceylon, South India, Malaya, and Java. In Ceylon, it was first brought to notice in 1906, but it was not until 1909 that it assumed a serious aspect. About the latter year it was discovered in Malaya, and recorded under the name of *Diplodia rapax*; it was said to be likely to prove as dangerous as *Fomes*, if not worse, but events have not borne out that prophecy. The disease is usually extremely rapid in its action when it does occur, but it has not proved as dangerous as was at first anticipated.

Botryodiplodia Theobromae is an extremely widely distributed fungus, and has been recorded for almost every country in the tropics. But as the original description was incomplete, and the fungus is highly variable, it has received an extraordinarily large number of different names. Among these are *Macrophoma vestita*, *Diplodia cacaoicola*, *Lasiodiplodia Theobromae*, *Diplodia rapax*. As far as is known at present, *Botryodiplodia Theobromae* is the earliest name, and consequently the one which must be used. Bancroft found, on material attacked by *Botryodiplodia Theobromae*, an ascigerous fungus, *Thyridaria tarda*, which he considered the higher stage of the former, but the general opinion is that this assumption is unproved.

This fungus is known to grow on Cacao (stems, roots, and pods), Sugar Cane, *Albizzia moluccana* (roots), Papaw (stems), Mango (fruits), *Castilloa* (stems), and many other plants. In Ceylon, it has been found (1) on *Hevea brasiliensis*, killing back the main stem, or causing the death of "stumps," or living as a saprophyte on dead *Hevea* stems and pods; (2) on Cacao as a wound parasite which kills back the twigs, as a saprophyte on diseased Cacao pods, or causing a dry canker on large branches; (3) on *Castilloa* stems which had been previously injured by fire; (4) on dead Papaw stems, in which case it is merely saprophytic; (5) on wounds on the stems of old Dadaps and on decaying Dadap logs; (6) as a saprophyte on felled stems of *Ficus elastica* which were healthy when cut; (7) on pruned stems of *Albizzia moluccana*, which it entered through the cut surface and killed down to the base; (8) on Tea, as the cause of a serious

root disease; (9) on the roots of Coconut palms killed by *Fomes lucidus*.

The above is a formidable list of plants which can serve as hosts for *Botryodiplodia Theobromae*. Yet, in spite of that, it has never caused much serious damage on *Hevea* in Ceylon. It is generally distributed, but in the majority of cases it is only saprophytic, though it does sometimes become a wound parasite. If dead branches are regularly removed and burnt, it is not likely to cause much loss.

Fusicladium Stem Disease

A stem disease, attributed to a species of *Fusicladium*, was discovered in Java in 1907 by C. Bernard and described by him as follows:

"I have on several occasions received for examination material attacked by a black canker of the stem, caused by a fungus belonging to the genus *Fusicladium*; I have not been able to determine the species. The disease is not yet serious; on two different estates it had attacked a group of a dozen trees. A little later, on one of these estates, the disease attacked a new group of about forty trees, of which thirty died. This spot was about half an hour distant from the first.

"The disease begins on pruned branches, and on the tops of stems which have been pollarded. The leaves wither, turn yellow, dry up and then fall. The flow of latex diminishes rapidly and soon ceases altogether, and after a few days the tree is dead. Sometimes only the upper parts die, and new shoots are produced below the part attacked. The bark on the diseased part cracks and scales off; and, between it and the wood, in addition to a number of insects whose occurrence is only secondary, there is found the fungus which causes the disease, its mycelium forming a blackish down on the surface of the wood. With the aid of the microscope, brown, uniseptate conidia, characteristic of the genus *Fusicladium*, are easily found among the mycelium. The hyphae are brown, septate, and branched; after they have destroyed the soft parts of the cortex and the bast, they penetrate into the young wood and give it a dark colour.

"This disease is contagious, since it spreads to neighbour-

ing trees. The conidia enter the stems through accidental wounds, or, as already stated, through the wounds resulting from pruning or pollarding, and the mycelium proceeds from the top of the stem to the base."

The treatment for this disease is the same as that recommended for Die-back. Nothing further has been recorded about this disease, and the symptoms so closely resemble those of the Die-back caused by *Botryodiplodia Theobromae*, that it would appear probable that the two diseases are identical.

Mouldy Rot of the Tapped Surface

This disease was first recorded from Malaya in 1917. It usually begins as a series of small discoloured blotches, darker than the normal tapped cortex, which afterwards spread and unite to form an irregular band, parallel to and about an inch above the tapping cut. Or the infection may begin from a single spot and spread out in all directions over the tapped surface. The course of the disease is rapid, and in a few days the affected areas become quite rotten. They then acquire a greyish " bloom " which is particularly noticeable on wet mornings, or develop a white felted covering. This covering usually consists chiefly of saprophytic fungi which settle on the decayed tissue.

Later, the decayed surface turns black and becomes sunken. The disease then penetrates into the wood and spreads downwards vertically behind the untapped bark, the affected wood turning black. Large open wounds extending to the wood are caused on the tapping surface, and if tapping is continued the disease follows the tapping cut down the stem.

The fungus which causes this disease is a *Sphaeronema*. Its mycelium is dark coloured and gives the blackened appearance to the affected cortex. Its fructifications, which are also black, appear in large numbers on the diseased surfaces under favourable conditions. They are quite small, up to about one-hundredth of an inch in diameter, and one twenty-fifth of an inch high, but they can be easily detected with a hand lens. Each consists of a minute spherical base, surmounted by a long cylindrical neck. The spores, which

are produced within the base, ooze out from the apex of the neck in a sticky mass, and are washed away by the rain, or transferred mechanically from tree to tree. Insects are commonly found on the decayed areas, and they may assist in distributing the spores. A second type of spore, more resistant to drying, is produced within the decayed tissues and on the surface.

If the disease is not checked, it will spread over and destroy the whole of the tapping surface. If new cuts are opened without previous treatment of the affected surfaces, they soon become infected. Stripping for Brown Bast should not be carried out in infested areas, as the stripped areas are very liable to attack.

Tapping should be stopped on affected trees for at least a month. In bad cases it may be necessary to rest the trees for six months. The affected areas should be painted over with Brunolinum, or Solignum, or Jodelite. It is not necessary to cut away the infected tissue. Daily painting with a disinfectant solution should be adopted over the whole estate. When the affected trees are again taken into tapping, new cuts should be opened on another section if possible; if that is not practicable, the new cut should be four inches below the old one.

It is considered that infection is carried by the tapping knife. All tapping knives in use on an infected area should be sterilised by boiling, immediately the diseased trees have been treated.

If required, the general condition of the estate should be improved by thinning out, etc.

In Ceylon, a similar appearance, particularly as regards the occurrence of a white fungus patch on the renewing bark, has been noted. The cause, however, was different, the appearance being only another manifestation of Claret-coloured Canker. In these cases, the discoloured patches usually occur singly and in contact with the tapping cut; they have been found to be continuous with patches of Claret-coloured Canker in the untapped bark, and the sporangia of *Phytophthora Faberi* have been found, together with saprophytic fungi, in the white fungus covering. Up to the present, the *Sphaeronema* of Mouldy Rot has not been detected in Ceylon.

Thread Blight

The name Thread Blight is applied to a mycelium which runs in white strands, about the thickness of coarse thread, over the stems and leaves of shrubs and trees (Fig. 17). It is generally found on the smaller twigs, and consequently in the upper parts of bushes, or on branches of trees at a considerable height above the ground. It is not in any way connected with mycelium in the soil, but grows entirely on the plant. There are several different species of Thread Blight, perhaps the best known being those which attack Tea in Northern India. It is not an easy matter to distinguish between the different species, because in the majority of cases the fructifications of the fungus have not yet been discovered. In Ceylon, at least four species are known to be present, but none of them has caused any serious damage.

Fig. 17.—Thread Blight on *Hevea* branch (Malaya). $\times \frac{1}{2}$.

Thread Blight has been recorded on *Hevea* in Malaya and Java. In the latter country it is stated that leaves and small twigs are killed by it.

In Malaya, Thread Blight was found by Bancroft in 1911 on *Hevea* and Camphor. The affected Rubber trees were seven or eight years old, and were situated near one another and close to a belt of virgin jungle. The leaves on the younger parts withered and, in some cases, became matted together in dense masses, while the younger twigs also died. The white strands in this case were about a millimetre in diameter, and ran sometimes in zigzag fashion along the branches. On the younger twigs they became thicker and repeatedly branched. When the thread met a leaf-stalk it grew along it, and so on to the under surface of the leaf, where it branched repeatedly and spread over the surface of the leaf

until the whole under side was covered with a white mass of fine fibrils. When the mycelium on one leaf came in contact with another, it produced a dense growth which fastened the two leaves together. In this way masses of dead leaves are formed, and they may remain suspended in the tree for some time, fastened to the branches by the cords of mycelium.

Bancroft's description of the damage caused by the fungus, and of the thread, thicker on the smaller twigs and spreading out so as to cover the whole of the under surface of the leaf, recalls a Thread Blight of North India; but in his description of the microscopic features of the thread, he does not mention the structures which are characteristic of that Indian Thread Blight.

Brooks stated that a white Thread Blight was of common occurrence on Rubber in Malaya, but caused little harm. The strands of the fungus ran long distances over the branches, matting the finer twigs and leaves together, and sometimes enveloping the leaves with a fine felt of hyphae and causing them to die. As the white thread was very variable in character, Brooks suggested that there was more than one species attacking Rubber in Malaya.

Richards has described the Malayan Thread Blight on Rubber in similar terms. "The mycelial strands of this fungus appear like white threads running along the smaller branches and twigs of affected trees, collecting and binding together leaves in bunches. Leaves are frequently killed, and sometimes small branches." Richards found a Thread Blight in fructification, and sent it to Massee, who named it *Cyphella Heveae*, but there is some doubt about this identification.

Most tropical countries appear to have at least two species of Thread Blight, one epiphytic and causing little or no damage, and the other parasitic. The specimen photographed (Fig. 17) is probably an epiphytic species.

There is no difficulty in detecting Thread Blight, as the bunches of dead leaves and leaf-stalks render it quite obvious, while the presence of white cords running along the stems and binding the dead leaves together makes its identification easy.

Thread Blight may be spread either by spores, or by dead leaves which bear the fungus being blown by the wind into

another tree. The latter method is clearly demonstrable whenever Thread Blight is prevalent, for cases can often be found where a dead leaf, or the remains of it, adhere to the stem at the point where the thread starts. When a leaf which bears the mycelium is blown into another tree and lodges against a branch, the mycelium attaches itself to the branch at the point of contact, and thence grows up the branch to the leaves, giving off threads to the smaller branches as it reaches them.

Where the trees are closely planted, or where their branches meet, the fungus can pass from the leaves or twigs of one tree to those of another which happen to be in contact with them.

As the fructifications of most of the Thread Blights are unknown, it might be supposed that a distribution by means of spores was improbable, if not impossible. That, however, would scarcely be correct. It does not follow that, because the fructification is not known, therefore it does not exist. The investigation of these Thread Blights, and similar sterile mycelia, suggests that though the fructification is not produced on the tree, it is highly probable that it does appear when the fungus is growing under other conditions, possibly after the dead leaves and twigs have fallen to the ground. An infection on trees near a piece of jungle may very probably be due to the conveyance by the wind of a leaf bearing the mycelium; but an infection on a tree in the centre of an estate, hitherto free from the disease, is more probably a spore infection.

The bunches of dead leaves and twigs, and small branches which bear the white threads, should be cut off and burnt; all the affected parts being removed. As a rule only small branches are attacked and little damage is done. Should the fungus be found to occur on large branches, it should be scraped off and the branch painted with Brunolinum, etc. The efficacy of this last treatment will depend on the particular species of Thread Blight concerned; some species, though killing the young twigs, do not appear to injure the older branches. All parts cut out should be burnt, to avoid any possible development of fructifications which might occur if they were left to decay.

White Stem Blight

This disease has been observed in Ceylon on several occasions, but in general only on a few trees in each case. It is really a form of Thread Blight, but it is usually sent in as an early stage of Pink Disease.

It generally attacks one or more of the larger sub-erect branches, and causes a white, sometimes pinkish, patch along the under side, which may extend for a length of six feet along the branch and half-way round it (Fig. 18). Frequently rather broad white streaks start from the edge of the patch and run irregularly upwards, sometimes extending over the upper side of the branch and uniting again with the patch on the other side. When viewed from the ground the branch appears to have been given a very thin coat of whitewash, but when it is cut down and examined, all the minute scales of the outer bark are clearly distinct, and there is no general covering of mycelium. This distinguishes it from early stages of Pink Disease, in which the bark is usually covered with fine silky threads.

Fig. 18.—White Stem Blight. × ½.

On careful examination, however, a white thread will often be found running over the whitened patch. This is most easily seen on the white lateral streaks, where it is usually situated down the middle. On the large patch it is not so easy to make out, and there it is frequently interrupted, *i.e.* after running for a length of a few inches it disappears, and reappears again higher up. The thread is white, usually smooth, and about the thickness of cotton at most: it is thinner than the average Thread Blight. At the upper margin of the white patch there is often a fringe of fine, white hyphae.

In the commoner Thread Blights, the superficial mycelium on the stem usually occupies a very narrow line, being limited to the visible thread and a very short distance on either side. In White Stem Blight, however, the thread gives off hyphae which run over the stem, usually between the small bark scales, and these give off still finer hyphae which penetrate the scales. All these hyphae are invisible to the naked eye, but they loosen the bark scales, and consequently make the stem appear white. The white colour is due to the action of the fungus on the scales ; it is not the colour of a covering of mycelium. When the affected stem dries, the minute scales drop off like bran.

The fungus also occurs on Tea, and on that it whitens the branches completely, and travels to the leaves, which it attacks and kills rapidly. It has not yet been found on the leaves of *Hevea*, or on branches less than an inch in diameter. The greater development on Tea is probably to be associated with the higher humidity which prevails around the Tea bush, because of its dense growth and low habit.

In the case of Tea, the finer hyphae penetrate through the cortex and into the wood, though up to the present it has not been observed that the stems are killed thereby. There is no doubt, however, about its action on the leaves. In the case of *Hevea*, the cortex underlying the normal bark layer usually appears quite green and healthy, even when the patch is six feet in length. But in some instances it has been found that, in the centre of the patch, the cortex is dead and brown throughout, and has separated from the wood, while a white film of mycelium occurs between them. The effect in such cases is similar to that of Pink Disease, though it is apparently much slower, and confined to one side of the branch. Whether this effect is general has not yet been determined.

The white patches should be tarred, or painted over with tar and liquid fuel, or with 10 per cent Brunolinum Plantarium, etc. It does not appear to be necessary to prune off the branches.

Care must be taken not to confuse with this disease the round, or oval, white patches caused by the growth of lichens on the stem. Lichen patches are smaller, more definitely circular, and are not, as a rule, confined to the lower side of the stem.

Horse-hair Blight

(*Marasmius equicrinis*, Mull)

Horse-hair Blight is the name given by the planter to a thin black cord of mycelium, somewhat resembling Horse-hair in size and appearance, which overruns the tops of bushes, or the lower branches of trees. Like the name Thread Blight, it includes the mycelia of different species of fungi. The common Horse-hair Blight of the Eastern Tropics is round, smooth, and usually more or less polished, but that of the Western Tropics is minutely hairy or silky.

Besides being different in colour and appearance, Horse-hair Blight differs from Thread Blight in its habit. As a rule, it does not adhere to the branch along its whole length, but only at certain points, where it is attached by small brown pads of mycelium. Moreover, it does not always pass to the leaf *via* the leaf-stalk, but may leap across from stem to leaf, or from one branch to another, by long free cords, and so involve the whole of the top of a bush in a tangle of black strands.

Horse-hair Blight is common on Tea, and it is frequently to be found on Rubber planted among Tea, more especially at the base of the stem up to a height of a foot from the ground. It is not parasitic, but lives on the dead, brown, bark scales. Consequently it is quite harmless, and its presence need not cause any alarm.

The common Horse-hair Blight of the East is the mycelium of a small mushroom-like fungus, *Marasmius equicrinis*. The fructification is rare on the mycelium which overruns the higher parts of a plant, but it is frequently present on the black cords at the base of a Rubber tree (Plate III., Fig. 2).

Top Canker

This name is given, in Ceylon, to a disease which affects the upper branches or stems of the tree (Figs. 19, 20). The bark splits longitudinally in lines a foot or more long, and forms, at first, long narrow scales. These scales split again transversely, so that a length of the stem is covered with more or less rectangular scales. These scales ultimately become friable, and often yellowish internally through decay.

The stem consequently becomes rough and scaly, in some

Fig. 19.

Fig. 20.

Top Canker. $\times \frac{1}{3}$.

cases only for a length of about a foot or so, but in others over its whole length. The patch is usually longer when thin

stems, about an inch in diameter, are attacked, than on thicker ones.

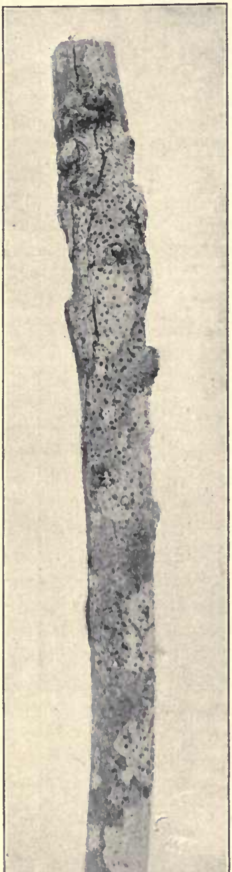


Fig. 21.—Top Canker. $\times \frac{1}{3}$.

In many cases, this effect does not extend through the cortex. In others, the disease penetrates to the wood, and causes an open wound, which becomes bordered by a healthy callus. In the most general case, the affected part bears one or more wounds in the centre, surrounded by a more extensive region over which the bark is only superficially scaly. Sometimes the wounds have healed normally, but the bark scales persist round them. When the scales are rubbed off, the patch is found to be surrounded by a well-defined vertical margin of healthy bark, especially at its upper and lower ends.

Probably because of the formation of successive wounds, the stem becomes thickened over the affected region, and on cutting the branch across, the marks of old wounds will often be found buried deep in the wood, even in places where the patch is merely scaly and no sign of a previous wound is evident externally.

The bark surrounding the scaly region, where it is not yet split, is often rough with small corky warts (Fig. 21). This formation of warts may extend almost the whole length of the stem.

Latex occasionally exudes from these broken patches, and runs down the stem, coagulating in streaks which subsequently blacken. Sometimes a rusty liquid oozes out, as in Claret-coloured Canker.

The cause of these scaly patches has not been ascertained.

It is usual to regard them as the result of the attacks of the fungus which causes Claret-coloured Canker, *Phytophthora Faberi*. The scales resemble those which are formed in that disease, and there is sometimes the same exudation of a rusty liquid, though the latter phenomenon appears to be infrequent.

The wounds and rough patches on the larger stems should be scraped clean and tarred. Smaller stems, on which the disease is more extended, should be cut out and burnt.

A Stem Disease of Seedlings

(*Pestalozzia palmarum*, Cke.)

Pestalozzia palmarum is the fungus which causes the well-known Grey Blight of Tea, and the common leaf disease of coconut and other palms. It occurs fairly frequently on old damaged leaves of *Hevea* towards the close of the year, but as it is much more vigorous as a saprophyte than as a parasite, there is usually some doubt whether it is the cause of the injury.

In several instances, this fungus has been found to attack the green stems of seedlings about a foot high. The stems are attacked at the collar and killed by the fungus for a length of about an inch. The death of this part is, of course, followed by the death of the whole plant, because the supply of water is cut off. The diseased part of the stem is white, and is separated from the green part above by a narrow red-brown line. This disease has been recorded from Java, as well as from Ceylon.

As *Pestalozzia* is, in general, only a weak parasite, it is probable that the condition of the nursery is a contributory factor in the incidence of this disease. The preparation of seed beds and the care of nurseries are more gardening operations than is the usual routine of a plantation, and in many cases they do not receive sufficient attention. The site of a nursery is usually governed by the available water supply, and the same ground is often used for nurseries continuously ; consequently it becomes sour, and quite unfit for the purpose, and the plants are weak and die, either because of the unfavourable conditions, or because they are unable to resist the attacks of feebly parasitic fungi.

The position of the nursery should be changed after each batch of plants has been reared, and the old ground allowed to lie fallow, and dug over repeatedly, before being used again. Soil sterilisation, either by surface firing, or by treatment with formalin or steam, is now extensively practised in temperate countries, in cases where the same soil must be used continuously, but such methods, or at least the latter two, are too expensive for adoption in estate practice where nurseries are maintained only for a limited period.

When diseases of this kind make their appearance in the nursery, all the plants attacked should be rooted out, and the affected patches, *i.e.* the bare soil, watered with a solution of Jeyes' fluid, in the strength of one ounce to a gallon of water. The shade should be removed as much as possible, at least at intervals.

Loranthus

Members of the *Loranthus* family are the Mistletoes of the Eastern Tropics. They are, of course, flowering plants, not fungi, but as they are semi-parasitic on trees and shrubs, they come under the notice of the plant pathologist. They are much more common in tropical countries than is the Mistletoe in Europe, partly because they are not so particular in their choice of host plants, and partly because there are so many different species, Ceylon, for example, having twenty-five of them.

The seeds of *Loranthus*, like those of the Mistletoe, are invested with a sticky coat, and when the fruits are eaten by birds, the latter get rid of the seed by rubbing their beaks along the branches of trees or anything else handy. The seed adheres to the branch and subsequently germinates. It will germinate anywhere, on telegraph wires, stones, posts, etc., but the young plant does not develop far, unless it is on a living branch. The "root" first produced develops a sucker which fastens the plant to the branch, and then sends out a root which penetrates through the cortex of the host, and runs along inside the branch.

The *Loranthus* being green, it can obtain food by utilising the carbon dioxide of the air, after the manner of green plants in general; but it must derive its supply of water, nitrogen, and salts from the host plant. Consequently it is only

parasitic on the host so far as the latter are concerned, and is therefore only semi-parasitic.

The *Loranthus* plant grows into a bushy mass, usually with weak hanging branches. From the original point of attachment, many species send out roots which run along the outside of the branch, giving off, at short intervals, suckers which penetrate through the cortex. The base of the bushy growth generally becomes gnarled and massive, partly through the growth of the stem of the *Loranthus*, and partly through the development of a mass of wound tissue by the host plant.

The effect of the parasite on the host is usually very slow. As the *Loranthus* intercepts part of the water, etc., which should supply the apex of the branch, the latter ultimately dies back and breaks off.

Loranthus is not often found on Rubber in Ceylon, but it has been reported to be fairly prevalent in some districts in the Federated Malay States. The branches which bear the parasite should be pruned back below it. As the plant is evergreen, it is a conspicuous object when the *Hevea* is leafless. If it is allowed to grow for any considerable time, a large increase in the immediate neighbourhood may be expected, as birds are not likely to travel far before ridding themselves of the sticky seeds.

SUMMARY

STEM DISEASES

PINK DISEASE

(*Corticium salmonicolor*, B. and Br.)

Identification.—A pink patch, more or less cracked by short lines at right angles to one another, overlying the diseased bark (Plate V., Fig. 1); or diffuse bands of long, silky hyphae running longitudinally along the stem (Plate V., Fig. 2); or minute pink cushions in cracks in the bark (Plate V., Fig. 2); or orange-red pustules embedded in the bark; any two or more of these may occur together.

Occurrence.—Attacks the upper branches and stems of the tree, usually at a fork. All parts above the point attacked die.

Treatment.—See pp. 139-142.

Ustulina zonata, Lév.

Identification.—Bark and wood decayed and permeated by black lines. The fructification of the fungus appears as a circular plate, lying flat on the stem, at first white, becoming greenish, then purple-grey, finally black (Fig. 15). These plates are brittle when old.

Occurrence.—Attacks trees at a fork, and on old canker wounds, and on areas damaged by fire.

Treatment.—Trees attacked at a fork should be pollarded below the fork: where this form of the disease is prevalent, forks should be cleaned up and tarred. Canker wounds and scorched trees should be treated as early as possible to prevent attacks.

Death of Green Twigs

Causes various.—Wind, root disease, too frequent forking, *Phytophthora*, *Phyllosticta ramicola*, *Gloeosporium alborubrum* (Plate III., Fig. 1). Not serious in itself, but may be followed by Die-back.

Die-back

(*Botryodiplodia Theobromae*, Pat.)

Identification.—Tree dies back from the top, the branches being killed in succession, the lower parts meanwhile remaining healthy. Progress generally rapid. A brown slimy layer along the cambium in the dead parts. Bark finally covered with a black powder resembling soot.

Occurrence.—Usually attacks groups of trees up to a dozen.

Treatment.—Prune off the dead tops about a foot below the diseased part and burn them.

Fusicladium Stem Disease

Probably identical with Die-back.

Top Canker

Identification.—Swollen regions on the branches, covered with loose scales of bark, and frequently surrounding wounds which expose the wood (Figs. 19-21).

Occurrence.—Found on the upper branches and stems. More common in closely-planted Rubber.

Treatment.—Scrape clean and tar all wounds and rough patches on the larger stems, and prune off and burn the smaller.

Mouldy Rot of the Tapped Surface

(*Sphaeronema* sp.)

Identification.—Small discoloured patches, parallel to and about one inch above the tapping cut, which spread and unite into an irregular band: this becomes covered with a greyish mould.

Occurrence.—Occurs during continued wet weather, or in damp localities.

Treatment.—Thinning out; application of Brunolinum; preventive painting with Brunolinum, etc., after every tapping.

Thread Blight

Identification.—A white thread running along the upper branches (Fig. 17) and thence to the leaves, binding together the leaves and twigs in dense masses.

Treatment.—Cut off and burn the bunches of dead leaves and twigs, together with any small living branches which bear the threads. Scrape the threads off the larger branches and paint with Brunolinum, etc.

White Stem Blight

Identification.—Long white patches on the lower side of the branch extending half-way round it, and along it for a length up to six feet (Fig. 18). A fine white thread runs along the whitened patch, and the upper margin of the patch may show a fringe of hyphae.

Occurrence.—Usually found on large sub-erect stems and branches.

Treatment.—Paint the patches with 10 per cent Brunolinum Plantarium, or tar, or tar and liquid fuel.

Horse-hair Blight

(*Marasmius equicrinis*, Mull.)

Identification.—A black shining cord which forms a tangle over stems and leaves, and produces small, mushroom-like fructifications (Plate III., Fig. 2).

Occurrence.—In the case of *Hevea*, frequently occurs at the base of the stem, attached to the outer brown bark.

Treatment.—Not necessary, as the fungus is not parasitic.

Stem Disease of Seedlings

(*Pestalozzia palmarum*, Cke.)

Identification.—A white zone at the base of the stem separated from the green part above by a red-brown line.

Occurrence.—Attacks seedlings about a foot high, in nurseries, and kills them.

Treatment.—Uproot diseased plants, and water the affected patches with a solution of Jeyes' fluid, one ounce to a gallon of water. Reduce shade as far as possible.

Loranthus

Identification.—Bushy evergreen growths, parasitic on the upper branches, and ultimately killing the part of the branch beyond them. Easily seen when the *Hevea* is wintering.

Occurrence.—Distributed by birds which rub the sticky seeds off their beaks on the branch.

Treatment.—Prune off and burn affected branches, about a foot below the plant.

CHAPTER VI

NON-PARASITIC DISEASES, ABNORMALITIES, ETC.

Brown Bast

This disease has been known to exist in Java since about 1912, though it appears to have been confused there at first with Claret-coloured Canker. It was recorded in Malaya and Borneo in 1916, and in Ceylon in the following year. It usually attacks trees in tapping, but cases on untapped trees have been discovered in Java and Malaya.

The first indication of the disease is usually that the tapping cut has gone dry, it may be along the whole of its length or only along part of it. When examined closely, the part which is not yielding latex is seen to be discoloured, but it is not, as a rule, so evident a discoloration as that of Claret-coloured Canker. It may be greyish or greyish-yellow, with small pale brown, or yellow-brown spots, or the discoloration may appear as a definite pale brown line on the tapping cut near the cambium (Plate V., Fig. 5).

In some cases the discoloured cortex appears sodden, and exudes a watery liquid when pricked; hence it was originally designated "water-logged bark." This appearance, however, is not universal. Between the brown line and the cambium the cortex is still laticiferous, and hence, if it is pricked down to the wood, latex will issue from this inner layer. Therefore, the fact that a tree yields latex when pricked is not evidence that it is not attacked by Brown Bast.

When the cut becomes dry in parts, the latex which issues above the non-yielding part often coagulates when it arrives at the latter, and blocks the cut, so that the latex which exudes subsequently runs over down the stem instead of flowing along the cut to the vertical channel.

Sometimes the latex from cortex just attacked is very thick and coagulates on the cut. In one instance, where the disease began on the tapping cut, the latex coagulated in an irregular curtain, two or three inches deep, suspended from the cut.

In order to make certain that Brown Bast is present, the tapping cut should be reopened, and the fresh cut immediately examined for the presence of discoloured spots, or the continuous brown line. The bark beneath the tapping cut should be shaved away in thin layers until the laticiferous tissue is reached. If Brown Bast is present, the cortex will be found to be yellowish-grey, with greyish streaks and patches, and here and there red-brown streaks and spots (Plate V., Fig. 7). In well-defined cases there is a continuous discoloured layer about one or two millimetres from the cambium, and no latex exudes until the shaving has penetrated beyond this layer.

The course of the disease may apparently take several forms. One observer states that a brownish-yellow discoloration first appears between the stone-cell region and the laticiferous region of the cortex, and is followed soon after by another layer of the same character deeper in, nearer the cambium. In other cases, the outer layers of the cortex are slightly discoloured and speckled with small yellow and brown spots, but the first continuous brown line appears near the cambium. In many cases, the brown line near the cambium is the first definite sign.

It is characteristic of this disease that, in general, it does not extend completely through the cortex to the cambium, but stops short about a millimetre or so from the latter. In normal tapping the latex tubes at that depth are not drawn upon, and hence the affected cut appears dry. But latex can be obtained by tapping deeper. This gives another practical indication of the presence of this disease. Brown Bast should be suspected if the cooly has to tap deeper than usual to obtain a satisfactory flow.

In one instance where the disease began on the tapping cut, a continuous brown line appeared near the cambium, but latex still issued in a line of minute drops outside the discoloured layer. In this case the bark was renewed bark, and the line of drops of latex was situated near the red

outer layer. Such an appearance, however, can only be temporary.

The disease derives its name from the occurrence of the brown layer near the cambium. After that has made its appearance the whole of the cortex external to it may turn brown and dry up, and be cut off from the living inner layer as a thick dead scale. A cortex, say eight millimetres thick, will then consist of a dead outer layer, six or seven millimetres thick, overlying an inner, living, laticiferous layer only one or two millimetres thick (Plate V., Fig. 6). This scale may extend over half the circumference of the tree, and for several feet in a vertical direction. As a rule, it does not thin out gradually at the margin, but terminates in a more or less perpendicular thick edge. It is usually hard and brittle, and scales off in large patches, but cases have been observed in which it was soft and friable. When old it cracks, and, where the disease is prevalent, these cracks, generally more or less vertical, are commonly an indication that a tree is affected.

The disease is usually found in the lowest two feet or so of the stem, though cases have been seen up to a height of ten feet. It can descend for a considerable distance, two feet or more, down the tap root, and the dead bark scales on the root are usually more cracked, vertically and horizontally, than those on the stem.

If left untreated the diseased bark may form a thick brown scale, with the normal white inner surface of separation, which is irregularly pitted and elevated, and in this case appears moister than usual. If this scale is prised off, the thin underlying layer of laticiferous tissue appears at first sight to be normal, and one is apt to imagine that with the removal of the scale there is an end of the trouble. A further examination, however, disproves that. The exposed white tissue very frequently turns brown rapidly, especially in wet weather. If it is lightly scraped before that happens it will generally be found to be discoloured, pale brown or greyish - brown, beneath the outer white layer, while on cutting deeper it will be found to be mottled with yellow or red-brown points, or streaks, or sheets, presenting what has been called a "pepper and salt" appearance. Thus the underlying laticiferous tissue is not normal.

It is the fact last noted which makes Brown Bast such a serious disease. If the living tissue beneath the scale were normal, the only effect of the disease would be the temporary loss of a certain area of bark, and though this would mean a loss of revenue until the bark had renewed to a tappable thickness, it would not involve any permanent injury to the tree. But the occurrence of yellow or brown spots, etc., within the inner layer brings about complications. For these spots are areas or regions of dead, or abnormal, tissue, and it is round such masses that nodules are usually produced. Consequently, it is found that, if left untreated, the Brown Bast patches which have apparently healed themselves develop masses of nodules.

Nodules, then, follow attacks of Brown Bast. It must not however be imagined that all cases of nodules are old cases of Brown Bast. Nodules, in the most general case, develop round points or small masses of abnormal tissue, and it merely happens that in cases of Brown Bast such points and masses occur in the renewing bark. But they also occur without any previous attack of Brown Bast.

The foregoing description applies to a very general, if not the most general, form of the disease. In many cases, however, nodules arise in the affected cortex without any preliminary formation of a thick dead scale, and in others the affected cortex may remain unchanged, except for a slight scaling at the tapping cut, for at least two years.

In Java it has been stated that the disease generally originates on the tapping cut and works downwards. In Ceylon it more usually begins in the untapped bark below the tapping cut, and the cooly taps into the diseased area as tapping proceeds downwards. When the disease is first noticed on the cut, the bark beneath is commonly affected for a distance of eight inches or so. As an extreme case, I have seen a tap root and stem attacked, to a total length of four feet, when the tree had just been noticed to have gone dry. The tree had been in tapping for about a year, and about six inches of bark had been worked through. This was no doubt the result of an attack at the collar, and the tapper tapped into the diseased bark.

In the Federated Malay States it is found that the disease may begin either at the tapping cut or at the collar. In the

former position, in the early stages, the bark is only affected for a short distance below the cut, and for a smaller distance in the renewing bark above it. Infection is at first confined to the section of the tree which is being tapped, and it frequently remains confined to one tapping section, especially if the vertical channels have been cut fairly deeply. The disease travels downwards more rapidly than upwards and eventually reaches ground level. Collar infections originate at ground level, or just below it, and spread up and down. The upper edge of the affected bark in this case is frequently irregular, with finger-like projections of diseased tissue. As the tapping cut descends the stem, one or two of these projections may be encountered, and the tapping cut becomes dry in parts ; as the cut moves lower, these increase in width until a region is reached in which the whole of the cortex along the tapping cut is affected, and the cut consequently becomes completely dry. The disease travels down the tap root and along the laterals, and on the latter it may be confined to the under surface in contact with the soil.

As a rule, trees are not killed by this disease. One instance, however, has been observed in Ceylon in which several trees died, or rather were destroyed, after an attack of Brown Bast. The trees had been heavily scraped to a height of about six feet, and had been attacked subsequent to the scraping. The bark was killed completely, right down to the wood, and cracked horizontally and vertically into rectangular scales. On some trees this took place all round the stem for a length of two or three feet. No effect was observable in the crown of the trees, and the tapping cut below the affected zone yielded latex as usual. But as the trees were not treated, boring beetles attacked the diseased tissue and riddled the stems to such an extent that they broke off in a moderate wind.

The cause of Brown Bast has not yet been ascertained. It seems reasonably certain that no fungus is to be found in the affected tissues. In one quarter it is claimed that the effect is due to bacteria, but little evidence has yet been put forward in support of that contention, and the experiments of other investigators with such bacteria as have been found in cortex affected by Brown Bast have proved negative. The opinion is gaining ground that the effect is due to physiological

causes, *i.e.* that it is not caused by fungi or bacteria, but is due to some interference with the normal physiological functions of the tree, or is a response to some condition induced by the treatment to which the tree is subjected.

In the discoloured region the spaces between the cortical cells round the latex vessels are filled with a brown or yellow substance, and the walls of the latex vessels may be coloured yellow. This brown substance gives the reactions for wound gum, and hence has a composition similar to that of wound gum, though its actual nature is still in doubt. Consequently, it has been deduced that Brown Bast is the result of tapping. Rands writes: "It appears, therefore, that Brown Bast is an accentuated condition of gum secretion probably resulting from the response on the part of the tree to the present methods of tapping." Bobilioff, who dissents from the view that the brown substance is wound gum, agrees that the disease is physiological. Both these investigators appear to regard it as due to a degeneration of the tissues owing to the removal of latex from the cortex.

Rands divided 100 trees, free from Brown Bast, into two groups of 50 each, and tapped them with two cuts on one-third circumference, 20 inches apart, the one group daily, the other six times a day. At the end of twelve days, 20 of the second group were running dry and showed the brown substance in the intercellular spaces and in the latex vessels, but no trees in the first group were affected.

Bobilioff isolated, on each of 10 trees, an area of cortex, 22 inches long and 11 inches wide, by cutting round it a deep channel extending to the wood. Thus no latex could flow into the isolated area from the surrounding cortex. Each isolated area was then tapped daily with a single cut extending right across it. After one and a half month's tapping eight cuts were dry, while the yield of the other two was below the average. A microscopical examination of the remaining cortex showed that all the isolated areas were attacked by Brown Bast, five of them severely.

The earlier methods of tapping were certainly more severe than anything in vogue at the present day. In the era 1905–8 it was customary to tap a tree by six cuts, a foot apart, on half the circumference, and to strip one side completely in a year. Yet Brown Bast was unknown in those

days. Perhaps it may be suggested that the cortex was removed so rapidly that the Brown Bast effect had no opportunity of becoming evident. One of the chief differences between ancient and modern tapping is the number of cuts to the inch.

A latex tube is formed by the perforation of the cross walls in a longitudinal row of cells. It is now known that, after the perforation of the cross walls, the latex tube is not simply a storage place, but a continuous living cell, retaining a protoplasmic lining and the nuclei of its constituent cells. Hence the latex is a special cell sap, and, in tapping, one is repeatedly extracting cell sap from a particular series of cells. It is conceivable that the continual extraction of latex from, or through, the same lengths of latex tubes might lead to their degeneration.

On the evidence it would appear that there is a probability that Brown Bast may be due either to too frequent tapping or to too fine tapping, or to prolonged tapping on the same section. But up to the present it has not been possible to associate Brown Bast with any one of these factors. In countries where daily tapping is the rule there is a tendency to attribute Brown Bast to that factor, and on one estate in Ceylon on which an extensive experiment on daily *v.* alternate-day tapping is being carried out, Brown Bast is worst on the area tapped daily. But the majority of Ceylon estates tap on alternate days, without enjoying any immunity from Brown Bast, though the percentage of trees attacked appears to be smaller than in countries which favour daily tapping.

Detailed records of the tapping history and yields of individual trees have rarely been kept, but where these are available it has not been found possible to correlate the incidence of Brown Bast with the frequency of tapping, or the yield of the tree, or with prolonged tapping on one section. Further investigations are required before any conclusions can be arrived at.

Treatment of Brown Bast

Several methods of treatment have been proposed for Brown Bast on the assumption that the disease was infectious; and even if it is physiological they may still be necessary in

order to prevent the development of nodules. These methods will be described later. Meanwhile attention may be directed to other possibilities.

In several instances, where trees have gone dry because of an attack of Brown Bast, and tapping has been continued whether the trees yielded latex or not, the renewed bark has been healthy and free from nodules. Such tapping is equivalent to a long-drawn-out scraping, and it removes the cortex in which nodules might develop, without the danger of causing wounds which attends the more immediate methods of treatment. No spread of the disease by means of the tapping knife has been observed during this tapping. This method is worth trial in all cases where neither scales nor nodules develop immediately. If nodules form, the tree should be treated for nodules. The success of this method may depend upon the height of the tapping cut from the ground; it has been found successful in the case of cuts, originally at 15 inches from the ground, on which the remaining bark was worked through within eighteen months.

In the Federated Malay States it is recorded that, of the trees which run dry, many never develop burrs or nodules, but recover after resting. Trees which develop burrs are said to occur in definite, easily recognised areas, while on numerous estates burrs seldom occur. Hence it is recommended that trees attacked by Brown Bast should be rested, except on those areas where burrs are known to develop; in the latter cases all trees attacked by Brown Bast should be treated immediately. This experience would appear to be at variance with that in Ceylon, where trees which have been rested for two years have been found to be still affected by Brown Bast at the end of that period, though no nodules had been formed and the bark had only scaled off slightly along the tapping cut and the vertical channel. It is of course impossible that cells which have degenerated should become normal again; all that could be obtained by resting is a new growth from the cambium behind the degenerated layers in the ordinary course of growth of the stem.

With regard to both the foregoing methods, it must be borne in mind that, as has been known for very many years, there is a type of tree which will go dry at intervals without being attacked by any disease. Such trees have usually a

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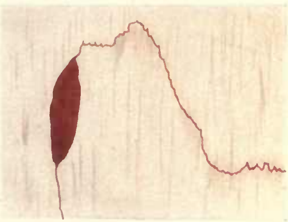

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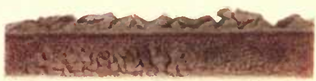

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STEM AND ROOT DISEASES

smooth bark, which is uniformly yellowish and granular internally. These trees again yield latex if rested, but it has always been recommended that tapping should be continued, because the renewed bark is of normal quality.

The more immediate methods of treatment which have been advised aim at the complete removal of all the affected cortex, so that the formation of nodules is prevented. Three methods have been adopted in different countries, viz. scraping, stripping, and tarring.

In the scraping method the diseased cortex is shaved away until latex begins to exude, and is then painted with Brunolinum Plantarium. A piece of sacking should be placed round the base of the tree to receive the scrapings, and the latter should be burnt. The scraping will, in general, leave some areas of diseased tissue on the stem, and these will be killed by the Brunolinum. Further, the penetration of the Brunolinum into the remaining laticiferous layer will partly kill it, and so put out of action the abnormal streaks and points round which the nodules develop; but the Brunolinum solution should not, of course, be so strong that it kills the cortex down to the wood. The strength which may be used without causing wounds must be determined by trial, as estates apparently differ in this respect. Twenty per cent Brunolinum Plantarium should be tried first, and if that causes wounds when applied immediately after scraping, application on the day after scraping should be tried. If the twenty per cent solution does not cause wounds, the strength should be increased.

When the cortex dies back after scraping and application of Brunolinum Plantarium, it does not necessarily follow that the death of the cortex is due to the Brunolinum; and a few trees should be treated by scraping only, to see whether the cortex dies back when the Brunolinum is not applied. If, in the latter case, the cortex dies back, the patches must not be scraped so deeply.

The stripping method of treatment has been largely employed in Sumatra, and is officially recommended in Malaya. In this treatment the whole of the affected cortex is stripped off down to the wood. Thus, not only is all the diseased tissue removed, but also the inner layer, overlying the cambium, in which the nodules develop. The method is

no doubt a drastic one, and it would be supposed that it could only result in the formation of a large wound, but experience is unanimous that, when properly carried out, a covering of renewed bark appears over the whole of the exposed wood surface within a fortnight. The procedure is as follows.

Ascertain by light scraping how far the disease extends, collecting all scrapings as in the previous method ; and then, with a sharp knife, isolate this area by vertical and horizontal cuts which extend to the cambium, including a margin, about an inch wide, of healthy cortex. Shave this isolated area to half the thickness of the cortex. Carefully lever up the lower edge with a knife, taking care to press on the cambium as little as possible, and then take hold of the free edge and peel off the whole of the shaved cortex. The preliminary shaving is required, as the unshaved cortex is not sufficiently flexible to be stripped off without breaking.

Holes appear in the renewed bark wherever the stripped surface has been touched. If exposed to sunlight the bark does not renew over the wood, and if exposed to rain, holes are formed where the raindrops fell on, or the rain-water ran down, the stripped surface. Hence the operator should work under the shelter of a screen, and the treated surface must be protected from sunlight and rain by cadjan or other screens.

Screens may be made of any available material, but whatever screen is used it must not touch the stripped surface. Cadjan screens, or grass screens braced with bamboo, about three feet by two feet, are convenient. Two of these should be leant, overlapping, against the tree, with the lower edge on the ground about a foot away from the trunk, and tied to the stem by a cord at the top. To prevent rain running down the stem over the stripped surface, a piece of cloth, dipped in paraffin wax, is placed round the junction of the screens with the tree, where the wax should cause it to adhere. It is necessary, for good renewal, to admit light, but not direct sunlight. For this purpose a third screen is laid against the tree, beneath the other two, and is withdrawn daily for a few hours. White waxcloth aprons protect the stripped surface and admit light, but are expensive.

Stripping cannot be done when the tree is wintering, as the cortex will not then separate readily from the wood. It

should not be done during droughts, as the exposed area may then dry up, or during prolonged heavy rains, when the stripped surface may be attacked by fungi.

Some cases of injury to the stripped surface by insects or fungi have been reported from Malaya. A mole cricket has been found to nibble the surface, and so cause large wounds. Two unidentified fungi have been found to attack the surface, one of which produces white silvery strands of mycelium which kill the underlying tissues, while the other forms white powdery patches which become black. Mouldy Rot and Black Thread also attack newly-stripped surfaces, and hence this method should not be adopted where these diseases are prevalent.

Unfortunately, it has not yet been found possible to treat the stripped surface with any preservative solution without damaging the renewal. Covering the surface with paraffin wax is said to have been successful. The wax is melted, is kept hot by means of a portable fire, and is sprayed on with a garden syringe immediately after stripping. When the cortex renews, the wax falls off, and may be collected and used again. If the direct rays of the sun fall on the wax, it melts, and the sunlight injures the renewing tissue ; hence the use of wax should be discontinued six weeks before the wintering season.

Stripping has been carried out successfully on an experimental scale in Ceylon, but it has not been generally adopted. In Malaya, after extensive trials, it appears to be falling into disfavour owing to the injuries caused by it. The method would appear to be one which can only be done successfully by skilled labour under the closest supervision.

The tarring method was invented by Harmsen in Java, where it is said to have given very good results. The extent of the affected patch is determined, as above, and it is then partly isolated by deep horizontal and vertical channels. These channels should not extend to the wood, as a completely isolated patch may die back. If the affected patch does not extend across the vertical (tapping) channel, the latter may be deepened to form one boundary. The patch is then shaved to half the thickness of the cortex, and is then painted with hot coal tar, heated until it begins to bubble. If the disease extends into the renewing bark, the latter should have the outer brown layer only removed and then tarred.

It is claimed that the application of hot tar promotes the growth of the underlying cortex, and that in some cases the treated bark is re-tappable, *i.e.* gives a good flow of latex, within three months.

In cases where a thick, brown, dead scale has formed, this should be prised off. If the stripping method is being used, the underlying layer may be stripped in the usual way, though the operation will require great care. In general, however, it will be found more satisfactory to paint the underlying layer with 10 per cent Brunolinum without scraping.

In old cases, where nodules have already formed, the nodules should be cut out in the usual manner and the wounds painted with 10 per cent Brunolinum, or tarred. In such cases wounds will inevitably be caused where the nodules have become united to the main wood of the stem.

The whole of the area affected by Brown Bast must be treated. This will often involve the treatment of the tap root and the lateral roots. The holes which are dug round the trees should be left open and drained so that water does not lodge against the treated patches.

Brown Bast, as a rule, attacks the side which is, or has recently been, in tapping. This is a point against the adoption of Change-over systems of tapping. If one side is tapped out completely, the other is not likely to be attacked by Brown Bast in the meantime. But if the first side is left when, say, six inches have been tapped, the remaining bark may be found to be attacked by Brown Bast, when it is desired to return to it.

Nodules

The development of burrs on the stem of *Hevea* was first noted in the East in 1904, and it is now of common occurrence in all rubber-growing countries. The affected stems may bear a single, large, more or less uniform swelling on one side of the tree, extending from the base to a height of two or three feet, or a number of smaller, sub-hemispherical protuberances clustered together in an irregular mass. Frequently elevated ridges extend from the edge of the larger swellings over the surrounding area of the stem. In the days of pricker tapping the clustered burrs were the more frequent,

but at the present time the type generally met with is the single large swelling. Where burrs of several years' growth

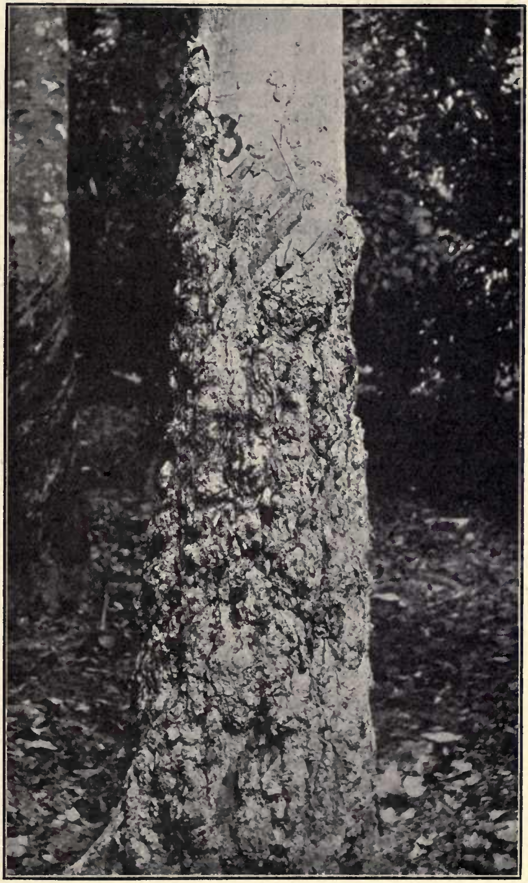


FIG. 22.—Burrs on a *Hevea* stem.

are present, the whole of the lower part of the stem becomes gnarled and knotted, and tapping is impossible.

These swellings are the result of the formation, in the cortex, of a mass of wood, which is generally known as a nodule. At first this woody mass is small, and its presence is only indicated by a slight elevation of the bark; in this stage the nodule is embedded in the cortex, not united to the wood of the stem, and can be shelled out quite easily with a penknife. Each nodule possesses a cambium of its own, distinct from the main cambium of the stem. Consequently, it increases in size by the addition of layers of wood all round it; and as it grows larger it causes the characteristic swellings. In its older stage, or sometimes when the nodule is quite small, it develops points on the inner surface which unite with the main wood of the stem, so that ultimately the wood of the stem and the nodule are continuous over part of their opposed surfaces.

The bark over the nodule, or more especially over the grouped forms, becomes deeply cracked and fissured, and often splits off in large scales. Latex sometimes exudes from the cracked cortex and runs down the stem. In many instances the latex from the cortex surrounding or covering the nodule is yellow, varying from a pale yellow to a deep chrome. Sometimes the cortex separates from the stem internally, and latex collects in the cavity, subsequently forming a rubber pad. Rubber pads up to three ounces in weight have been taken from such situations.

Nodules in their earliest stages differ very much in shape, and the ultimate form of the burr, or swelling, apparently depends to a great extent on the initial shape of the core or nodule. But practically all of them can be classified under two types.

In the one type the nodules are at first small, spherical, or elongated bodies, one or two millimetres in diameter. These may increase in size until they become large, more or less hemispherical, or cylindrical masses. If several of these small nodules occur close together their cambium layers may meet and unite, thus producing a multiple nodule, but such a one would generally even up in further growth into the same shape as the foregoing. Often a large nodule in the course of its growth meets and fuses with small nodules, and the latter then appear as excrescences on the surface of the larger. Instances of the fusion of small nodules are shown

on Fig. 23. In this way a sheet of wood may be formed, though it would appear that, as a rule, the sheet nodules belong to the second type.

In the second type the nodule at first is a network of wood, or a sheet perforated with small holes, whichever one chooses to regard it. Such a sheet may be only a millimetre thick, yet it may extend up the stem for a length of several feet. At first it is embedded in cortical tissue, the latter

FIG. 23.—Nodules; early stages. Natural size.

being continuous from side to side of the nodule through the perforations, but as its cambium adds new layers of wood the holes are closed up, and it becomes a thin continuous sheet, sometimes with depressed lines here and there which mark the sites of previous holes. The most remarkable feature about these plates is the large area they extend over while they are still so thin that they can scarcely be extracted entire. When these plate nodules thicken, the resulting burr may be several feet in length, but comparatively slightly elevated. One such nodule, taken from a tree which had

been tapped by a pricking method, was 4 feet 9 inches long, 6 inches broad, but only 1 inch thick.

The surface of a nodule is usually marked with raised ridges, running in parallel undulating lines, and here and there forming closed curves. A similar pattern sometimes occurs on the stem wood behind the nodule.

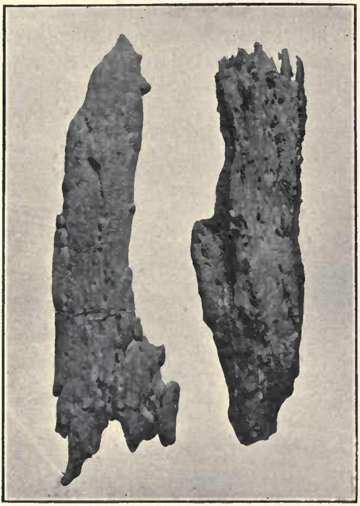


FIG. 24.—Nodules. $\times \frac{1}{2}$.

The formation of one nodule appears to be followed by the production of others in the surrounding cortex. It would seem that, once this formation has been initiated, the stimulus spreads over the stem in all directions from the point of origin. Crops of small nodules frequently occur round large nodules, especially when they are grouped in clusters. Nodules have not, however, been observed on the parts of the tree below ground, nor had they been found on exposed lateral roots, even in cases where the stem was badly burred down to the ground level, before the appearance of the nodules following Brown Bast.

On cutting across a small nodule, a dark-brown point or line is found in the centre. In the case of thin plate nodules a line extends along the middle of the nodule, almost from side to side, but in small, spherical "pea" nodules only a minute brown point may be evident. This coloured point, or line, is the section of a line, or sheet, of cortical tissue round which the nodule has been built. As was first shown by Bateson, and confirmed by Bryce, this browned tissue consists of one or more latex vessels, surrounded by cells which contain a dark-brown tannin, and outside these a few cortical cells without tannin.

The formation of nodules, in the most general case, is due to an alteration in the contents of the latex vessels. The walls of the latex tubes become yellow, and the neighbouring cortical cells are filled with a brown tannin. This sets up an " irritation " in the surrounding tissues, with the result that a cambium is formed, which buries the abnormal latex vessels in a mass of wood. If only a short length of the latex vessels is concerned, the nodule is at first small and spherical or cylindric, but when the latex vessels are altered over a large area a plate is formed, or the vessels are encrusted in such a way that the nodule assumes the network pattern of the latex vessel cylinder. The altered latex vessels which are enclosed in the nodule belong to one latex vessel cylinder, or row, only.

The cause of the alteration in the latex vessels has not been discovered. It has not been found to be associated with the attack of any insect or fungus, and it would appear that a solution of the problem must be deferred until more is known about the chemical changes concerned in the formation of latex.

Bryce distinguishes four types of nodule, according to the character of the tissue which induced their formation and is embedded in the centre of the woody mass. These are as follows :

(1) Nodules formed round altered latex vessels.

(2) Nodules formed round lesions in the cortex into which latex has oozed and coagulated.

(3) Nodules formed round areas into which latex has oozed and coagulated without any lesion of tissue : in these cases the coagulated latex occupies the intercellular spaces.

(4) Nodules formed round areas of cortex from which latex may be entirely absent.

Bateson recorded what was at first considered to be another type of nodule from Malaya. These were found on untapped bark on trees about five years old, and were small spherical bodies of the kind to which the name " pea disease " is often given. They did not occur promiscuously over the stem, but were confined to the leaf-scars.

The leaf-scars of *Hevea* are well marked on the twigs, where they form brown, semi-oval, or horseshoe-shaped patches. On the older branches they are larger, but on

rough-barked trees there is usually no trace of them left on the old stem. On smooth-barked trees, however, the leaf-scars persist on the main stem, and are evident for many years as horizontal lines, up to four inches long, with a depression in the centre.

On examination of these leaf-scar nodules, a short thread of rubber was found in the centre of each. Bateson accounts for the presence of this by supposing that it is part of the contents of one of the latex vessels which accompanied the vascular bundles from the stem to the leaf. When the leaf falls, the ends of the vascular bundles, which supplied the leaf with water, etc., remain embedded in the cortex, and as the stem increases in circumference they are carried sideways and become widely separated. The strands of coagulated latex may then give rise to nodules, as in the case of tapped trees.

Nodules were especially common in renewed bark, a few months old, after pricker tapping, whether the tree had been tapped by using the pricker only, or by using the pricker after the cortex had been excised to the customary depth with the knife. It was formerly thought that this might be due to the stone cells which occur in large numbers in renewed bark after pricking, but further examination has shown that these nodules contain latex vessels in the centre.

During recent years, nodules have been found to develop in large numbers after attacks of Brown Bast. This fact was originally discovered by Rutgers. The effect does not follow an attack of Claret-coloured Canker as a rule.

When *Hevea* cortex is attacked by Brown Bast the greater part of it ultimately forms a thick, dead, brown scale, leaving only a thin laticiferous layer, usually less than two millimetres thick, overlying the cambium. This layer at first sight appears healthy, but, on cutting into it, it is found that it contains minute points or patches or streaks of discoloured tissue. Nodules subsequently develop round these discoloured specks, and Bateson has shown that the nucleus of the nodule, in this case also, contains altered latex vessels. The production of nodules after an attack of Brown Bast is thus due to the presence of altered latex vessels in the remaining cortex, and it is consequently to be regarded as a secondary effect of the disease.

To sum up the matter briefly, nodules develop round abnormal regions in the cortex, most usually round altered latex vessels. A part of the cortex becomes abnormal, and the tree proceeds to put it out of the way by burying it in a mass of wood. Each nodule is a coffin. Unfortunately the process of coffin building, once begun, is continued indefinitely.

Small nodules may, in some cases, work out. Bryce records the finding of nodules of fair size in dead bark scales which were on the point of dropping to the ground, on *Hevea* trees thirty-five years old. It is not uncommon to find small nodules with their outer surface exposed, and it is probable that these would dry up completely and be shed with the dead bark.

Nodules are usually found on tapped trees. Bateson, as noted above, has recorded the formation of pea nodules on untapped trees in Malaya, but, in Ceylon, Bryce states that the common type of nodule, that which develops round altered latex vessels, does not occur on untapped trees, the nodule-like structures on the latter being globular shoots.

According to Bateson, severe tapping favours the development of nodules. Tapping certainly appears to induce nodule formation in some trees, while others, equally tapped, remain free from them. There appears to be a probability that some strains of *Hevea* are less subject to this abnormality than others; hence freedom from burrs is a character which should be required in the selection of seed bearers.

Nodules should always be cut out. If they are discovered while still small, they can be taken out without damaging the cambium of the main stem; but if they have become united to the main wood of the stem, their removal will cause a large open wound. In any case, however, they should be taken out, if the tree is to be kept, as the burred area is, or will become, untappable, and its extension over the whole of the lower part of the stem is only a matter of time. In taking out these large nodules the whole of the wood of the nodule should be removed, down to the main wood of the stem, and the latter smoothed off. The wound should then be tarred. Large nodules, extending to a height of three feet, and over half the circumference of the tree, have been successfully removed from trees up to eight years old.

Globular Shoots

Bryce examined a large number of untapped trees in Ceylon, varying in age up to eleven years, without finding any instance of the occurrence of true nodules, *i.e.* woody masses formed round altered latex vessels. Of 2000 seven-year-old trees examined on one estate, about six per cent bore structures which resembled nodules, but these differed from true nodules in not having latex vessels or tannin cells in the centre. These structures are not formed by the deposition of wood round altered latex vessels, but from dormant buds, and are technically known as globular shoots. It is scarcely possible to distinguish globular shoots from nodules except by a microscopic examination, but a rough method is provided by the fact that on cutting across a small nodule a dark-brown point or line is found in the centre, whereas no such discoloured tissue occurs in a globular shoot. The chief difference from the practical standpoint is that globular shoots never grow into large woody masses, about one inch being the maximum diameter noted.

In one instance, where young *Hevea* trees had been pollarded, a strong development of globular shoots occurred just below the cut surface. These appeared as spherical or oval protuberances, with a woody core up to about an inch long, the core being quite unconnected with the main wood of the stem. Subsequently these protuberances developed strong shoots.

Globular shoots have also been observed in old leaf-scars, in the callus at the edges of wounds, and at the fork of trees with forked stems. In the old leaf-scars they develop from the dormant or latent buds, and may occur singly, or several may be fused together in a horizontal row along the leaf-scar. It is probable that all "nodules" reported on untapped trees, and all which "sprout," *i.e.* develop leafy shoots, are really not true nodules, but globular shoots.

Fasciation

Instances of fasciation of the stem of *Hevea* are not rare. Most estates, during the first two or three years after planting, are able to show one example at least, and it has been

estimated that one case occurs in about every 10,000 trees. As a rule the trees affected are from one to two years old.

In what is perhaps the commonest case the green shoot gradually expands at the apex and becomes flattened, and the edges of the flattened stem increase in thickness more rapidly than the centre, so that it becomes vertically fluted along the middle line and ultimately divides into two stems. Each half now grows independently, and in the course of its growth it curves over towards the other half, until the two stems cross. After crossing, each stem expands into a thin plate with a variously scalloped margin along the thinner edge, but in many cases it makes several complete turns before finally spreading out.

The wing-like expansions are covered with small projecting ridges, usually arranged in transverse lines; these ridges are the scars of aborted leaves. The thinner edge of the wing is also covered with aborted leaves, or stipules, crowded together. Frequently normal leaves are borne in large numbers on the stem just below the point where it divides, and also along the more regular, thicker edge of the wing. Consequently, a dense, bushy cluster of leaves is sometimes produced, which hides the fasciated stem completely.

Figure 25 shows a specimen in which one side especially has executed numerous turns before finally expanding.

The example shown in Fig. 26 is formed by the gradual thinning out of the stem on one side, instead of down the middle, as in the more general case. Such one-sided specimens are not uncommon, but they are not usually developed to such an extent as the one photographed.

Fasciation in some instances (other than *Hevea*) is due to the attacks of insects or fungi, but in the majority of cases nothing definite can be stated except that they are certainly not due to either of those causes. There is no reason to believe that either insects or fungi are responsible for fasciation in *Hevea*.

The abnormal tops should be cut off. If left alone the fasciated part of the stem dies, but before that happens a new shoot generally develops lower down the stem. It has been stated that in Java cases have occurred in which, after a

fasciated stem has been cut off, the new shoots which subse-

FIG. 25.—A fasciated stem. $\times \frac{1}{3}$.

quently developed have also been fasciated. This has not been observed in Ceylon, but it is possible that it might

happen if the top were pruned off close to the abnormal part. It should be cut off about two feet below.

FIG. 26.—A fasciated stem.

TWISTED SEEDLINGS

Nursery plants with stems twisted at the base are of frequent occurrence. In the most general case the stem

makes a complete turn, either in a regular curve (see the fifth from the left in Fig. 27), or in a combination of curves and abruptly angular bends; in other cases there are two complete turns, and in a single instance three have been observed. The curves are rarely all in the same direction, and the resulting combination is frequently so complicated that analysis fails to afford any adequate explanation. It may be noted that the examples given here had been grown in free soil, and do not owe their origin to the presence of stones in the nursery.

As a rule, these twisted plants are discovered when they are about to be planted out in the field; at that time the coils are generally fused together, and would ultimately, if the plants had been allowed to grow, have formed a solid mass at the base of the stem. The specimens shown in Fig. 27 were nursery plants eighteen months old.

After several chance observations on the production of twisted stems, the following experiment was carried out:

(*a*) 50 seeds were planted horizontally with the flatter side downwards.

(*b*) 50 seeds were planted horizontally with the flatter side uppermost.

(*c*) 50 seeds were planted vertically with the micropyle, *i.e.* the hole through which the root emerges, downwards.

(*d*) 50 seeds were planted vertically with the micropyle uppermost.

(*e*) 50 seeds were planted horizontally, and on their narrower side.

The results of this experiment are illustrated in Fig. 28. No. 1 (from the left) is a typical seedling of lot (*a*) in which 48 germinated, all normally. No. 2 represents the seedlings of lot (*b*) of which 49 germinated, all normally. No. 3 is a seedling of lot (*c*), one of 47, all of which were normal, though the seeds were raised above the soil. Nos. 4 and 5 are typical of the seedlings of lot (*d*), in which 45 seeds germinated; 27 of the seedlings had a knee bend, as shown in No. 4, and in 9 others this was accentuated into the shape of an N, while the remaining 9 formed complete loops as illustrated in No. 5. No. 6 is a representative seedling of lot (*e*), of which 39 seeds germinated, all normally.

Experiment (*d*) was repeated with 20 seeds; 15 of these

germinated, 11 with simple knee, or N-shaped bends, and 4 with complete loops. It would appear, therefore, that

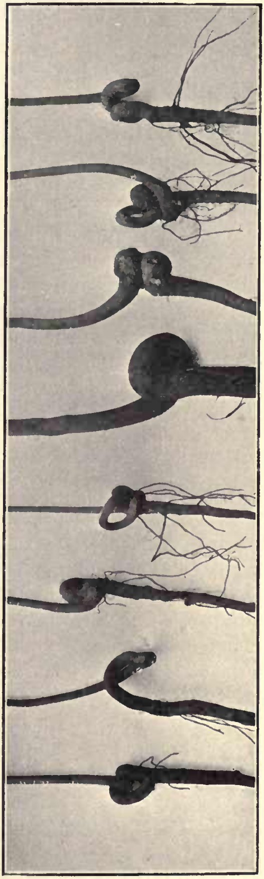


FIG. 27.—Twisted seedlings, eighteen months old. $\times \frac{1}{8}$.

FIG. 28.—Twisted seedlings, one month old. $\times \frac{1}{2}$.

planting the seed with the micropylar end uppermost favours the production of twisted seedlings.

When the seed germinates, the developing root (radicle) pushes off the circular cap which closes the micropyle, and emerges as a white stump, about three or four millimetres in diameter, with a truncate flattened end. As it lengthens, the flattened end becomes slightly conical and its margin develops a number of minute points. The conical central point is the developing tap root, while the marginal points are the developing lateral, or secondary, roots. It is a peculiar feature of *Hevea* that the secondary roots at first grow much more rapidly than the primary, or tap, root, and serve to fix the young plant as the radicle curves downwards.

The two seedling leaves (cotyledons) remain within the seed and absorb the food stored up round them. But the stalks of these leaves are lengthened until they project outside the seed for a length of about a centimetre. The young shoot lies between the two leaf-stalks, its tip being situated just within the seed. After the tap root has developed, the shoot emerges sideways from between the leaf-stalks in a loop. This loop then turns upwards, and, as it elongates, the tip is pulled out of the seed, and the young shoot straightens out and becomes vertical.

When the seed is planted with the micropyle uppermost, the radicle, on emergence, points vertically upwards, and subsequently bends over. Consequently, unless the seed is planted deeper than usual, the radicle protrudes above ground before it begins to curve downwards. The secondary roots are then produced in the air, and in the extreme case they may wither before reaching the soil. But in all cases, even when the radicle does not project above the soil, the emergence of the looped shoot is considerably delayed, because that does not occur until the radicle has curved over so that its tip points vertically downwards and the secondary roots have been produced. During this delay all the parts outside the seed, including the two leaf-stalks, become much thicker than in normal germination. This thickening has two results: it makes the curve in the base of the stem so rigid that it cannot subsequently straighten, while the two leaf-bases hold the shoot, when it endeavours to pull itself out, as in a vice. These two factors cause all the twists.

If the looped shoot becomes free, the only curve or twist in the stem is that which is caused by the downward curve of

the radicle, and this takes the form of a knee or an N bend, as in No. 4 of Fig. 28. Nos. 2 and 3 of Fig. 27 are similar bends.

But in many cases the loop is held so firmly by the thickened leaf-stalks that it cannot pull out. No. 5, Fig. 28, shows this; the loop has not straightened out, but the tip of the shoot has emerged from the seed and has curved upwards on the outside of the seed-leaf stalk, forming a complete loop. Nos. 4 and 7 of Fig. 27 are examples of the same condition.

In some instances the tension in the loop of the young shoot when it endeavours to straighten out is so great that it breaks close to the tip. The shoot has then no growing point at the apex. Headless seedlings of this description, with a shoot about eight inches long, but without a terminal bud, are not uncommon. They usually produce shoots from the buds in the axils of the seedling leaves, and thus double-stemmed plants are formed.

Cork Warts

This phenomenon has, up to the present, only been observed on two occasions, in the one case on the upper part of the main stem of an old tree, and, in the other, on a young tree, about five inches in diameter. The stem bore numerous outgrowths of bark, like small pyramids, usually six-sided and flat-topped. Towards the base of the stem these were crowded together side by side in large patches, covering the whole circumference. Higher up they occurred on smaller isolated patches, while, at a height of about three feet, solitary pyramids emerged through the bark. In some places they were arranged in curved lines (Fig. 29).

The individual pyramids are usually erect, but sometimes curved. Some attain a height of an inch, though most of them do not exceed three-quarters of an inch in the only available specimen. All of them, however, project above the surrounding bark. At the base they are up to half an inch broad, and diminish in breadth to about a quarter of an inch at the apex. Several may be united from base to apex at first, and separate later. Their sides are marked with lines

parallel to the base, as though they were built up of thin layers one above another.

The cortex surrounding these outgrowths appears normal. Beneath them it is greatly reduced in thickness, and consists of a thin, laticiferous layer, only about one millimetre thick, just enough to hold the pyramids together. The pyramids are composed entirely of cortical tissues; very few stone cells are present in them, and these usually occur as isolated cells, not in groups.

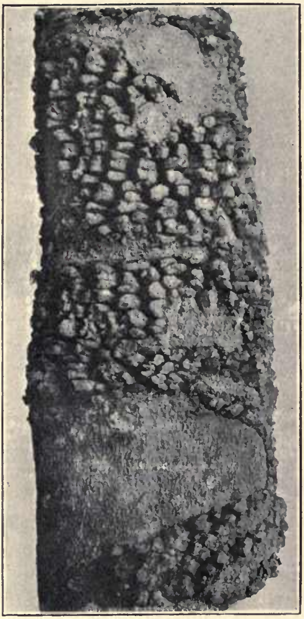


Fig. 29.—Cork warts. × ⅓.

No fungus has yet been found to be associated with this formation.

Malformed Stems

In a few cases, young trees, about three or four inches in diameter, have stems which are covered with rounded protuberances over their whole length. These protuberances resemble the swellings caused by nodules, but on cutting into them it is found that they are not due to the development of woody masses in the cortex, but to swellings on the main wood of the stem. A similar effect has been observed to follow wounding on small stems, but in this case the swellings bore obvious scars, and on cutting into the wood the blackened surface of the old wound was found buried in the wood at a depth of about half an inch. In the most general case, however, the bark over the swelling is normal, and there is no evidence of previous wounding. Such trees have been styled "knobbed trees" (knobbel-boom) in Java.

In a somewhat similar case the protuberances take the

form of elevated rounded ridges running longitudinally up the stem. These ridges unite with one another here and there, and form a netted pattern with deep depressions in the meshes (Fig. 30). The appearance recalls that of one of the strangling figs (*Ficus parasitica*) overgrowing a stem. The bark over the ridges does not exhibit any signs of injury, and examination shows that the ridges are due to swellings on the main wood, not to a development of nodules in the cortex.

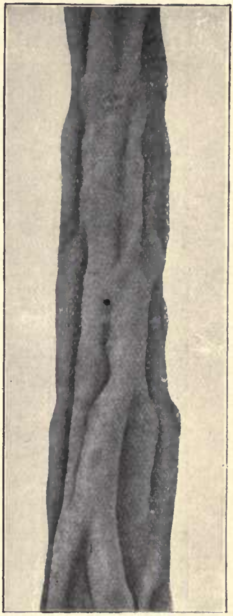


FIG. 30.—A ridged stem. $\times \frac{1}{6}$.

Young trees which have these malformed stems should be removed, as they do not develop into tappable trees.

A TWISTED *HEVEA* STEM

The photographs on Figs. 31, 32 show the stem of a two-year-old *Hevea*, two inches in diameter. At a height of six inches from the ground the stem makes three complete turns, and above these it is marked by a spiral groove for a length of nine inches. It will be seen from the photographs that this spiral groove begins near the upper edge of the last coil. The specimen had been broken before it came into my possession, and the fracture is shown by the line across the middle coil, where some of the bark has been broken off in the attempt to fit the two pieces together. The coils are quite free from one another, that is, they are in contact but not fused together. The stem has undoubtedly been coiled completely round three times; it is not merely grooved.

When the stem is broken across the middle turn it is seen to be coiled round a much thinner dead stem. This is evident in the second photograph, which shows the upper part of the stem inverted. From this the explanation of the pheno-

menon is fairly simple. When the young tree was planted out in the field it was, as usual, "stumped." The stem then died back to the next node, and the new leading shoot sprang from the bud at that node. But instead of growing straight up by the side of the dead stem, it coiled round the latter three times. The cause of this coiling is revealed in the

Fig. 31.

Fig. 32.

A twisted *Hevea* stem. $\times \frac{1}{6}$.

second photograph, where, still twined round the dead original stem, is seen part of some climbing weed. This climber grew up the stem of the young plant, and arrived at the bud just as the latter started into growth ; and in twining further round the dead part of the stem it carried the young shoot round with it. When the two reached the top of the dead stem the *Hevea* shoot grew straight upwards, and the

climber then twisted itself round the green shoot; this is shown by the spiral groove on the upper part of the stem, which is caused by the pressure of the coils of the climber on the young stem as the latter expanded. It is most probable that the coils of the *Hevea* stem were at first wide apart, but they have come into contact owing to its subsequent thickening. If the tree had been allowed to grow the coils would no doubt have become fused into a solid mass.

Scorched Trees

In many cases trees have been scorched by leaf fires, or by burning timber among the standing trees. Such trees are quickly attacked by boring beetles, and usually in a few days the bark is riddled with holes from which sawdust is falling down the stem. Afterwards *Ustulina zonata* frequently enters the damaged stems and completes the work of destruction begun by the beetles.

The scorched area most often extends in a long strip up one side of the tree, sometimes over half the circumference. If the fire has run rapidly through the field the damage may be confined to the renewing bark on the tapping surface. In some cases, when a leaf fire has progressed very rapidly, the chief damage may be on the opposite side to that first reached by the fire, as the leaves may burn more slowly on the leeward side of the tree.

The damaged trees should be treated as soon as possible, before they are badly attacked by borers. If they are severely damaged the whole of the scorched cortex should be cut out down to the wood, and the wound painted, first with Brunolinum, or Solignum, etc., and after that is dry, with coal tar. If only the outer parts of the cortex are damaged these should be scraped or cut off until healthy tissue is reached, and the surface then treated with Brunolinum and tar as above.

The affected area should be inspected daily for about a week to make sure that no damaged trees have been missed. It is often difficult to determine whether trees have been injured or not, as the damaged bark in some cases is not blackened in any way. Such trees may easily be overlooked, until the borers find them out. From several occurrences

examined in Ceylon it would appear that the borers attack the trees which are lightly scorched more readily than those which are severely scorched. If the bark is charred the beetles may not attack it at all.

Various methods have been suggested for the avoidance of leaf fires in countries where there is a definite dry season. Forking in the leaves in lines between the rows of Rubber appears to be one of the most reasonable. Leaf pits would seem, from a mycological point of view, to be open to suspicion, and they are likely to prove dangerous where *Fomes lignosus* prevails.

Where jungle roots, or felled *Hevea*, must be burnt among the standing trees, care should be taken to keep the heaps small. It has been suggested that the stems of the surrounding trees should be protected by having sheets of galvanised iron placed against them on the side nearest the fire, but obviously this would entail great expense, unless only a few heaps were fired at the same time. On many estates in Ceylon it is possible to find a more or less clear space at the bottom of a ravine, and it is worth while to expend a little more on the transport of the timber to such places rather than to run the risk of damaging the remaining trees.

Black Patches in *Hevea* Wood

When *Hevea* which has been in tapping for some years is thinned out, black patches, extending longitudinally up the stem, are often found in the felled logs. Sometimes the trees are split in the course of felling, and these patches thereby exposed. These have on several occasions been considered an indication of some new disease, but, though they are not normal, they are quite harmless, and are perhaps an inevitable consequence of tapping. They are sometimes called "burnt patches," which exactly expresses their appearance.

These black marks are the result of old tapping wounds, or of wounds caused by disease on the tapping surface or elsewhere, which extended to the cambium but did not set up a pronounced decay of the wood, *e.g.* wounds caused by Canker or Black Thread. When such wounds are healed the exposed surface is buried by a new growth of wood, but,

owing to the development of saprophytic fungi on it when exposed, or its oxidation through exposure, and subsequent changes after burial, the old surface is blackened.

Once the wound is healed the blackened area is buried deeper and deeper every year as the stem increases in thickness; and as the tree is not grown for timber, the hidden defect is of no importance. It can have no effect on the general health of the tree. When the tree is split, separation occurs most easily along the line of such a patch, because the layers of wood on the two sides of it are not organically united.

The trees which were tapped years ago by V's which extended to the wood now carry the pattern of the old tapping within the stem. Every wound on the tapping surface is duly recorded as a black mark. This is a somewhat depressing fact, but relief may be found in the knowledge that the black marks cannot be detected until the tree is cut down and split up.

The Effect of Lightning

The splitting of the stem by lightning, one of its most noticeable effects on trees in temperate climates, has not been observed on *Hevea*.

An indirect effect of lightning has been noted on several occasions in Ceylon. Two or three trees in the neighbourhood of a large rock suddenly died, the symptoms being similar to those of a root disease. In these cases the lightning struck the rock, and the trees in the immediate vicinity, though apparently uninjured, died in consequence. Similar instances have occurred in Tea.

Rutgers has investigated the effect of lightning on *Hevea* in Sumatra, where injury due to this cause is by no means rare in some districts. He classifies the effects under four heads:

(1) Single trees, or groups of trees, may be killed. In some instances one tree is killed, while the branches of the trees nearest to it are withered. In other cases one or more trees are killed, and the tops of the neighbouring trees wither, as in Die-back. The bark may be killed in a longi-

tudinal strip, sometimes running spirally down the stem, and the dead strip is soon attacked by borers.

(2) Trees which have been struck by lightning, but not killed, may bear short vertical wounds on the stem, sometimes arranged in a spiral line. These may be accompanied by a wound at the collar.

(3) The exudation of latex from the upper branches is regarded by Rutgers as another form of injury caused by lightning.

(4) The fourth type of injury is the scaling off of the

FIG. 33.—A lightning wound. $\times \frac{1}{2}$.

outer layers of the bark on the upper branches, apparently somewhat similarly to that known as "top canker" in Ceylon. Rutgers considers that this is probably due to lightning.

Where lightning has merely wounded a tree the cause of the wound is revealed by the peculiar character of the healing process. The margin of the wound, in the most typical case, shows a double callus. The effect of the lightning is not only to split the bark and wood radially for a short distance, but also to split it internally over a small area along the line of an annual ring. New growth of tissue then occurs from the cambium at the edge of the wound, as

in the case of ordinary wounds, and also from the separated surfaces of the wood along the line of the annual ring.

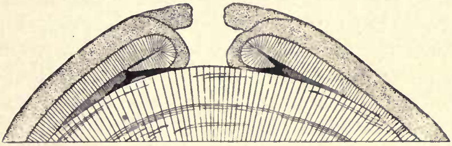


Fig. 34.—Cross-section of a lightning wound (diagrammatic).

Figure 33 shows a short oblique wound, caused by lightning, in process of healing, and the accompanying diagram (Fig. 34) was drawn from the cross section of it. The wood is indicated in the diagram by radial lines, and the cortex by the dotted areas. The projecting edges of the original cortex have died back, and a growth of callus has taken place over the edges of the wound from the original cambium. In addition, there is new growth (indicated by close lines) on either side of the wound in the split along the last annual ring. The black regions in the latter situation indicate dead tissue.

Fig. 35.—Lightning scars. × ¼.

The illustrations described depict a well-defined case. But many instances occur in which the scar is small, and no open wound is evident. In these cases the outer bark is often not cracked, and nothing is observed until it scales off and reveals the healed scar. Such occurrences are fairly common in one district in Ceylon, especially on two estates on opposite sides of the same valley.

The latter case is illustrated in Fig. 35. The stem,

which in the specimen photographed was five inches in diameter, is covered with circular or oval scars one or two inches in diameter. These scars occur scattered over the surface of the trees in large numbers. A small patch of bark, often longitudinally cracked, scales off, displaying the underlying scar, surrounded by normal bark which is usually slightly upturned round the edge. Sometimes exuded latex is present on the outer bark scale. The surface of the scar tissue is blackish, generally radially grooved and sometimes depressed in the centre. When the scars are large the stem is usually swollen, so that old examples are raised, as though a nodule had developed in the underlying cortex.

On stripping off the cortex over an affected patch, the main wood of the stem is found to be raised in a gradually elevated swelling under each scar. In some instances the surface of the wood is irregular, with projecting ridges and points, alternating with deep grooves and pits, while the inner surface of the cortex is correspondingly furnished with ridges and grooves, which key in with those of the wood. These irregularities are probably due to the interference of the two calluses.

Exudations of Latex

Exudations of latex from the upper parts of the stems or sub-erect branches of *Hevea* are not uncommon. The latex runs down the stem from one or more points, usually fairly close together, and coagulates in long black streaks. The phenomenon is sometimes referred to as "Weeping of the latex." The cause of this has not yet been ascertained. It was at one time regarded as an indication of Die-back, a view which has now been universally discarded; and it has also been suggested that it is due to the pecking of the stem by birds. Whatever the cause, it does not appear to be followed by any serious injury to the stem. Rutgers states that lightning is one cause of this exudation.

It may be laid down as a general rule that only healthy cortex can yield latex. If the cortex is attacked by fungi the latex coagulates in the latex tubes, at least in those diseases which have hitherto been investigated. It would

follow, therefore, that an exudation of latex indicates that healthy cortex has been cut or ruptured.

Spontaneous exudation of latex has been recorded in Brazil, where it is stated the trees sometimes burst and the latex flows out, forming a large lump of coarse rubber at the wound; and similar lumps have been observed in Bolivia.

The phenomenon is not confined to *Hevea*. Spontaneous exudation of latex has been recorded in *Manihot piauhyensis*, and it has been observed in *Manihot dichotoma* in Ceylon after heavy rains. It has also been recorded in *Ficus macrophylla*, in which case it was attributed to excessive pressure of the latex: in the latter it was stated that on strong branches the cracks attained a length of forty centimetres and subsequently enlarged to a breadth of five or six centimetres, but it did not occur on a regularly tapped tree.

In addition to this exudation of latex from the upper branches, which does not appear to be related to any disease, streams of latex flow quite commonly from stems attacked by Pink Disease or *Ustulina*. There are (at least) two possible explanations of this effect. In the early stages of Pink Disease, and also of Claret-coloured Canker, the disease may affect only the outer half of the cortex, the part next the cambium being as yet unattacked. If this diseased bark is bored by beetles they may draw latex from the inner sound tissue. This especially occurs if the beetles bore into the bark at a time when the latex will not flow; they then penetrate into the sound cortex without drawing latex at the time, but latex may exude from the hole later. Again, bark attacked by Pink Disease dries up, cracks, and splits away from the wood: these cracks may extend into the surrounding healthy tissue, and latex consequently exudes from the latter. When the fungus spreads further it involves the cortex from which the latex issued, and, therefore, the strands of rubber are found on the parts covered by the pink patch. Exudations of latex are not universal in cases of Pink Disease, but appear to be the more frequent in the cobweb stage.

Latex sometimes issues from renewing bark which has been treated with Brunolinum, Tar and Liquid Fuel, etc. In some instances the issue occurs at the edges of small tapping wounds, but in other cases the latex flows from

uninjured bark without any visible crack. Estates vary considerably in this respect, and the mixture which is used with impunity on one may cause bleeding on the next. But though the appearance is unsightly, the effect on the tree appears to be negligible.

Rubber Pads

This name is applied to lumps of rubber found between the wood and the cortex. They are usually circular and plano-convex, being flat on the side in contact with the wood and convex on the other. The bark over the pad may crack longitudinally and some latex may exude and run down the stem. Sometimes the overlying cortex decays, but it frequently remains healthy, especially when it has cracked, and forms two raised lips, or flaps, over the pad.

No single cause can be assigned for these formations. It is probable that several agencies may induce this result, but a satisfactory explanation of the most general case has not yet been formulated, for it would appear that as a rule the overlying cortex is not diseased. It would, however, seem that one essential condition for their formation is that the cortex must separate from the wood before the pad is formed. The latex collects between the wood and the cortex, and it would appear obvious that it cannot collect there before there is a cavity between them.

Pads sometimes form beneath bark which has been killed by Claret-coloured Canker. If the dead bark separates from the wood, latex may collect behind it, presumably owing to the extension of the separation along the cambium into the surrounding healthy tissue, but this is not of universal occurrence in the case of this disease. According to the accounts of Black Thread in Burma and Malaya, rubber pads are frequently formed beneath the decayed bark in cases of that disease, but they are not common under similar conditions in Ceylon. South states that it has been proved by inoculations that the *Phytophthora* of Black Thread disease can produce blisters on the untapped bark at a height of about four or five feet up the stem, the bark subsequently breaking up and disclosing a rubber pad underneath.

Quite an epidemic of rubber pads occurred in Ceylon

during the time the Northway tapping system with a rotating pricker was under trial. In the system in question the bark at the base of the stem was scraped up to a height of eighteen inches, and the pricker was run round the stem in horizontal lines, the latex being collected in a channel at the base. To assist the flow of latex the scraped part of the stem was syringed with water. In many instances blisters with rubber pads beneath them were formed, and these were cited as damage caused by the pricker, but it was clear that, in general, they were in existence before the pricker was applied, as they bore the marks of the pricker on the outer surface and often contained fragments of bark which had been pushed into them by the instrument. In some cases these blisters were the result of Claret-coloured Canker, but in others, though the bark died, no disease was traceable. All that could be said was that they followed the scraping and syringing.

An interesting case which probably has some bearing on the foregoing occurrence was noted during an attempt to infect *Hevea* stems with a possible parasitic fungus. A small patch on the stem was shaved flat, the fungus from a pure culture placed on damp cotton-wool, and this applied to the shaved patch and covered with a watch glass. As the weather turned dry, the cotton-wool pads were moistened daily. The inoculations were unsuccessful, but in several cases, both in the inoculations and the controls, a blister with a rubber pad behind it was formed, while the overlying cortex split longitudinally and latex ran down the stem. Thus the blisters and rubber pads were caused by keeping a small shaved patch of the stem continually moist.

CHAPTER VII

PREPARED RUBBER

Coloured Spots

Before the introduction of the present practice of smoking rubber, the appearance of spots or discolorations on biscuits, crepe, or sheet was a common occurrence. These still occur where the older methods of preparation are employed, but where the rubber is smoked, or thin crepe is made and dried by artificial heat, they are practically unknown. The spots developed when the rubber was drying, and it is no doubt owing to the more rapid methods of drying that the present immunity is due.

These discolorations appeared and disappeared in a most mysterious fashion. They might affect the whole product of a factory for a month and then cease to appear ; or almost all the factories in a district might be producing discoloured rubber for the same limited period.

As a general rule, smoked sheet or smoked crepe does not develop spots, nor do they often occur on crepe dried artificially. On biscuits or unsmoked sheet, red, blue, and black spots have been recorded. On thin crepe the spots may be red, yellow, blue, green, or black. Thick crepe is more susceptible to spotting than thin crepe ; but the pigment develops to a greater extent in thin crepe which is converted into thick crepe while still wet than on original thick crepe which has not first been rolled thin. According to Eaton, Grantham, and Day, the difference is due to the porosity of the rubber, the original thick crepe, made by minimum machining, being more porous, and, therefore, drying quicker than the blanket crepe made from thin wet crepe. The greater the amount of machining in the case of thick crepe, the greater the possibility

of spotting. These experimenters found that no pigment developed in blocked wet crepe if the pressure employed were sufficient to produce a solid block, and they attribute that to the exclusion of air.

In nearly all the cases investigated these spots have been shown to be caused by fungi or bacteria. These organisms, or their spores, are present in the freshly-coagulated rubber, and they grow in it during the time it is drying. When the rubber is dry their growth ceases. The latex may be infected in the field by wind-borne spores, or by the water used when it was customary to water the cuts in the belief that the flow of latex was assisted thereby. Latex diluted previous to coagulation shows a greater tendency to produce spotted rubber than undiluted latex, and the current belief that rubber is more prone to spotting in the rainy season has been attributed to the dilution of the latex by rain-water, and the consequent introduction of spores. In general, it is held that the latex is infected before coagulation.

Whether spots can arise by the infection of the rubber after coagulation has been much disputed. There does not appear to be any reason why infection should not occur during the creping process, from the water used, as the spores might then be embedded in the rubber, just as much as if they had been in the latex prior to coagulation. The point at issue, however, is whether spores which alight on the rubber during drying are able to produce these discolorations. Experimental infections of coagulated rubber by spraying spores over the surface, carried out by Sharples, failed when the rubber was hung up to dry, but were successful when it was rolled up; and this has been found to be the case in Ceylon. Arens infected freshly coagulated Ceara rubber with *Bacterium prodigiosum*, but how the rubber was kept is not recorded. It appears that, for surface infections to have any result, the coagulated rubber must be kept moist for a comparatively long time, and under the normal conditions of a properly-conducted drying house discolorations due to such infections should not occur.

Several investigations into the causes of these spots have been made, the most complete being those by Bancroft and Sharples in the Federated Malay States. There are considerable differences between the accounts of the various investi-

gators who have studied the problem, more especially as regards the particular species of fungus concerned in each case, but as a large number of chromogenic organisms is known, and very many of these may be introduced into latex with infected water, such differences are only to be expected. At the present time the subject is not one of pressing importance, for the reasons already stated, and the attention of mycologists has been directed to more urgent problems.

Sharples distinguishes two types of discoloration, viz. spots, where the discoloured area is usually small, and "flushings," where there is a broad, diffused patch of colour. His classification is followed below.

Red Spots

These usually occur on biscuits or sheet, but have been recorded on bark crepe and scrap. They vary in size up to half an inch in diameter, and are usually circular. The colour is a clear red and extends, as a rule, through the rubber: it gradually fades if the rubber is kept, but does not disappear altogether.

Brooks in 1911 recorded that these spots were caused by *Bacterium prodigiosum*, and that has since been confirmed by several investigators. This bacterium is of world-wide distribution and is the one which sometimes causes red spots in bread.

Bancroft obtained from similar spots a fungus which he recorded as probably identical with *Monascus heterosporus* (Schroet.), and reproduced the spots by spraying freshly-coagulated biscuits with the spores.

Black Spots

These have been recorded on sheet and crepe. According to Sharples the black spot is probably the commonest met with on the latter. The spots contain a mycelium which consists of chains of small rounded cells. In culture it forms a black layer of yeast-like cells with a sparse greyish mycelium. Sharples states that the cells are hyaline, and that the black effect is due to the reflection and refraction of

the light in the large masses of cells. He named the fungus *Chromosporium crustaceum.*

Bancroft investigated a "dark green or almost black" spotting on crepe, and found a fungus which he described under the name of *Spondylocladium maculans.* He also obtained the same fungus from a "yellowish-red colour," and thought that the two colours were produced at different ages of the same mycelium. No infection experiments were carried out.

Sharples considers that the fungus found by Bancroft was not the cause of the discoloration, and that the black spotting examined was probably the blue-black spot on crepe noted below.

Black spots have been observed on rubber biscuits in Ceylon. They appeared on the white wet biscuits a day or two after coagulation. The spots were circular, and varied in size from minute points up to patches an inch in diameter. The discoloration extended right through the biscuit, and, when it was dry, numerous dense black points were visible in each patch, in addition to the general black tint. These patches contained numbers of bacteria, together with minute particles of a black pigment to which the discoloration was due.

Blue-black Spot on Crepe

This spotting has been investigated by Sharples. The spots are a dense blue-black in the centre, fading out at the edge to a faint violet coloration. Successful infections were obtained with a green mould-like fungus, isolated from the spots, which was identified as *Trichoderma Koningi*, Oudem. Sharples states that this is a very common spot, and was always the first to develop in his laboratory on crepe rubber dried slowly.

Dark Blue Spots

A dark blue spotting observed by Bancroft on crepe rubber was found to contain stout, dark brown hyphae, consisting of short cells. The fungus in culture proved to be *Botryodiplodia Theobromae*, and Bancroft considered that the crepe was infected from poles of uncured jungle wood which

had been employed in the drying houses for hanging up the rubber. He found that the spots often occurred on the crepe in transverse bands recurring at intervals, and explained this distribution by supposing that the fungus, both in this case and that of *Spondylocladium*, had infected the rubber where it was in contact with the poles, the occurrence of the bands at intervals being due to the shifting of the rubber as drying advanced, and the consequent contact along a fresh surface. He obtained both the fungi mentioned from the surface of the poles in question.

Bancroft's findings have been criticised by Sharples, who was unable to obtain a discoloration by infecting latex with pure cultures of *Botryodiplodia Theobromae*. Sharples explains the occurrence of the spots in bands by the fact that the rubber in contact with the wood dries more slowly than the rest, and so gives the spores in the rubber a better chance to develop. The *Botryodiplodia* obtained by Bancroft in pure culture may have been derived from spores on the surface of the rubber, not from the mycelium in it. The spot would appear to be the same as the blue-black spot recorded by Sharples.

Transparent Spots

Clear transparent spots sometimes appear on unsmoked sheet or biscuit, a few days after coagulation, while the remainder of the sheet is still opaque white. These have been observed in Malaya and Ceylon. In the latter country they are generally circular, and sometimes up to two inches in diameter. The surface of the spot becomes covered with a delicate white growth, which consists of the conidiophores of the fungus in the spot. In Malaya it has been found that these fungi are of several kinds, usually species of *Penicillium* and *Aspergillus*.

Opaque Spots

According to Sharples, circular, white, opaque spots are very common on sheet rubber coagulated with acetic acid. Examination of the spots shows that they are due to the presence of fungus hyphae. Sharples considers that there is some relation between these spots and the common green mould, *Eurotium candidum*, Speg., which always appears on

the surface of badly-dried sheet rubber, or on any rubber which is allowed to become damp after having been dried. But no success was obtained with inoculation experiments.

Broad, Yellow, Diffused Flush

This coloration was found on sheet rubber by Sharples, who states that it is seen especially well in sheet rubber coagulated with Bush's powder. This is caused by a fungus which has been named *Penicillium maculans*. When latex has been intentionally infected with the spores of the fungus, a bright yellow colour is developed in broad patches over the coagulated rubber three days after inoculation. As the sheet dries, the yellow colour fades away slightly, but it is still quite obvious even when the rubber is dry.

The same fungus can give rise to an orange spot in crepe rubber.

Violet Flush

This occurs on sheet rubber, and has been investigated by Sharples. It is caused by a fungus, a *Fusarium*, the violet colour being due to a layer of spores.

Red Flush

This was observed on sheet rubber in Malaya by Bancroft. The discoloration extended through the sheet. A fungus, a species of *Mycogone*, was obtained from the discoloured areas.

Prevention of Spots

The chief factor in the prevention of spots or flushes is rapid drying. Unsmoked sheet and thick crepe are always liable to develop them, but it should be possible to avoid them without much difficulty in the preparation of thin crepe.

To assist in the prevention of these undesirable phenomena, the addition of formalin, or sodium bisulphite, to the latex before coagulation is recommended, though, according to Sharples, neither is sufficient to eradicate spots completely under practical conditions, and spots will develop if only the rubber dries slowly enough.

Sodium bisulphite has been largely used. It was intro-

duced as a means of manufacturing thin pale crepe, and a decrease in the amount of spotted rubber coincided with its introduction. This was probably due, in part, to the fact that the crepe, being thin, dried more quickly, rather than to any disinfecting action of the bisulphite. If too much bisulphite is added the rubber tends to dry more slowly, and the fungi have more opportunity of developing. Sharples gives the amount of sodium bisulphite which diminished spotting in his experiments as one ounce dissolved in one pint of water to each ten gallons of latex, added with constant stirring; that is, one part of sodium bisulphite to 1600 parts of latex. The amount necessary to prevent darkening of the rubber was given by Clayton Beadle, Stevens, and Morgan as varying from one part sodium bisulphite to 400 parts of latex to one part to 2400 parts of latex; the former is the maximum amount, and it is seldom necessary to use so much.

The quantity of formalin recommended for the prevention of spotting is one part formalin to 800 parts of latex, or 1 pint of formalin to 100 gallons of latex.

The use of acetic acid, or other coagulants, in excess of the amount necessary for coagulation increases the liability to spotting.

As surface infection after coagulation does not produce spots under ordinary conditions it is unnecessary to remove spotted rubber from the drying house, unless it is overcrowded and drying is thereby retarded.

Rubber prepared from diluted latex is more liable to become spotted than rubber prepared from undiluted latex, but spots are not likely to develop on smoked sheet.

The use of chinosol has been recommended in Java as a preventive of spots in crepe. Pure chinosol is dear, and commercial chinosol, or potassium oxychinoline sulphate, is said to be cheaper in proportion to its disinfecting power. It is used in 1 per cent solution—one part of the solution to 100 parts of latex. This is an expensive method, and it is admitted that with good drying it is unnecessary.

Spotting of Dry Rubber

It is sometimes found that rubber which was quite clean and dry when packed on the estate has arrived at the market

centres in a spotted condition. Eaton has shown that perfectly dry, clean crepe, if immersed in water for about five minutes, shaken to remove as much moisture as possible, and then rolled up into a cylinder, will develop orange, blue. and yellow spots.

The possibility of the development of spots in transit is thereby established, provided the rubber is allowed to become damp.

The Effect of Spotting on the Rubber

It has been generally believed that the growth of fungi and bacteria on raw rubber cannot have any influence on the quality of the rubber because no organism was known which could attack, and derive nourishment from, rubber itself. Those found in the crude rubber could only live on the sugars and proteids in the rubber. Söhngen and Fol cut out the coloured spots from a piece of crepe and compared the rubber with the uncoloured part. They found no difference in the analyses of the two, and the viscosity curves of the two portions were identical. Hence they concluded that the spots made no difference to the actual value of the rubber. It is to be noted that they did not carry out vulcanisation experiments.

Eaton, however, states that rolled-up, wet, thin crepe, in which spotting is always very pronounced, does not vulcanise as rapidly as rolled-up sheet, while, on the other hand, blocked, wet, thin crepe, in which spotting does not develop, has its rate of cure accelerated to a considerable extent. Experiments were made by rolling up wet "slab" crepe, *i.e.* slab which had been allowed to mature for six days, then converted into thin crepe, and immediately rolled up into a cylinder. In this case a marked development of spotting occurred, and the vulcanisation of the rubber was considerably retarded. Eaton states: "It is obvious that these chromogenic organisms utilise, destroy, or change the vulcanisation accelerator formed by the degradation of the protein by other organisms, so that it no longer behaves as an accelerator. The fact that these chromogenic organisms do not appreciably alter the vulcanising properties of ordinary slow-curing crepe can be explained on the ground that such

crepe contains little or none of these accelerating substances, and the organisms utilise the protein itself, which already exists in more than sufficient quantity in crepe for normal vulcanisation. Whether the protein in ordinary thin crepe is actually decreased by these organisms has not yet been ascertained."

The belief that fungi cannot attack rubber has been challenged by Söhngen and Fol. These experimenters prepared thin sheets of rubber, as free as possible from proteids, and succeeded in reducing the quantity of nitrogenous compounds to about 0.1 per cent. The sheets were then placed in glass dishes and moistened with a solution containing inorganic salts only, so that the only source of carbon in the medium was the rubber. The dishes were then infected with ordinary garden soil, with the result that two fungi developed on the rubber film. It was found that the rubber became friable and could easily be broken up, and holes occurred in the film at the spot where the fungi had grown. The two fungi were named *Actinomyces fuscus* and *Actinomyces elastica*. The authors consider that their experiments prove the existence of fungi which can attack and feed on caoutchouc, but there are several possibilities of error in the methods employed.

Rust

The term " Rust " is applied to a thin brown film which forms on the surface of smoked sheet as it dries. It cannot be detected until the sheet is scratched or stretched, when the surface film breaks and gives the sheet a somewhat powdery appearance.

Eaton, Grantham, and Day state that this is due to a thin film of dried serum, chiefly protein material. The sheet when hung to dry contracts, the serum in it being expelled and ultimately drying on the surface. Among the factors which may contribute to this defect they place (*a*) concentration of the latex, which results in the exudation of a concentrated serum, (*b*) allowing freshly-rolled sheet to remain in heaps, and (*c*) placing freshly-rolled sheet where other wet rubber has drained, so that it comes in contact with the old drainings. To obviate rustiness they recom-

mend (*a*) hanging the sheets to drain immediately after rolling, (*b*) making ribbed sheet instead of diamond sheet, and (*c*) washing the sheet after it has drained for an hour or so, and scrubbing, if necessary, before placing it in the smoke house. The latter method is the one most generally employed; on some estates the sheet is soaked overnight.

The subject has also been investigated by Hellendoorn, who has arrived at somewhat different conclusions. He claims that the deposition of a film of serum substances on the sheet causes "greasiness," but that "rust" is formed by the decomposition of this film by a micro-organism. This micro-organism flourishes only in the presence of air; hence rustiness usually appears on the surface which was uppermost in the coagulating pan. But if the sheets are hung too close together rust may form on the side which is then lowest, irrespective of its former position in the coagulating pan, owing to the development of a local damp atmosphere between the halves of the sheet. Rustiness is favoured by wet weather, and it can be developed at will by keeping freshly-rolled sheets in a damp atmosphere for twenty-four to forty-eight hours before smoking. It may be increased by lengthening the time between coagulating and rolling into sheet.

Hellendoorn shows that rustiness does not develop if the freshly-rolled sheet is disinfected by hanging it in formalin vapour; this is opposed to the theory that it is due to the "sweating out" of serum substances. Disinfection may also be effected by chinosol or bisulphite, or by immersion in hot water. The latter method is not recommended, because the rubber is injured by that treatment, while the other methods are not as efficient as rapid surface drying. If the air in the smoke house is sufficiently damp to favour the growth of the micro-organism which causes rustiness, the smoke does not entirely prevent its development.

Rustiness, according to Hellendoorn, is due to an infection, and the growth of the organism concerned is dependent upon the amount of moisture present. To prevent it, the sheets, immediately after rolling and washing, should be hung up, wide apart, in a well-ventilated place, or exposed to the wind, and after a few hours should be taken into the smoke house. Leaving the sheets to drip for a night should

be avoided. Rustiness may also be prevented by disinfecting the sheets, but as that is not so efficient that rapid drying of the surface can be neglected it is not to be recommended.

Hellendoorn states that soaking the sheets in water after rolling does not prevent rustiness, and may even increase it; that sheets from diluted latex develop rustiness more than sheets from undiluted latex; and that ribbed sheet has no advantage over diamond sheet in this respect.

Coloured Latex and Scrap

At certain times the scrap on the tree rapidly turns black on the surface. This is said to be more common in some countries when the trees are wintering. On some estates it is found to be worst in closely-planted fields. This effect is not due to a fungus, but to chemical changes which have not yet been completely investigated. It has been stated that, in some instances, rapid discoloration of the scrap is associated with insufficiently deep tapping, especially if it occurs at the upper end of the cut, while in other cases it is characteristic of individual trees.

A pink discoloration of the scrap is also known, but has not yet been explained. In this connection it is of interest to note that Eaton, Grantham, and Day record that slab rubber soaked in tannic acid turned pink.

Yellow latex is sometimes a sign of Brown Bast, but not invariably.

Tacky Rubber

Tacky rubber arises from the exposure of dry rubber to direct sunlight, or heat, or from the presence of copper or iron in the rubber. The copper may be present in the form of copper salts produced by the action of acids on any copper vessel used, or in particles of brass derived from the machinery. Particles of brass may cause green streaks which subsequently become tacky.

It is now generally agreed that there is no evidence that tackiness can be caused by fungi or bacteria, or that it can be communicated from one piece of rubber to another: and, though the subject is one which is open to further

investigation, it appears certain that tackiness is due to oxidation.

The evidence for and against previous theories, so far as there was any evidence, was summarised in the previous edition of this book, and, as it was based chiefly on speculations, it is unnecessary to repeat it. Since that publication, two series of experiments, which appear to be conclusive, have been carried out. In one of these, Eaton added copper sulphate to latex before coagulation, and showed that the rubber, when it subsequently became tacky, increased in weight: this increase is presumably due to the absorption of oxygen in the process of conversion of the rubber into resins.

Another series of experiments was carried out by Fickendey. Samples of rubber were exposed to the action of sunlight for eight weeks in sealed tubes containing different gases. Those in hydrogen, nitrogen, and carbon dioxide remained unchanged, but those in air and oxygen became tacky. The weight of the rubber in the last two cases had increased, and oxygen had been absorbed. Rubber kept under water remained sound, but rubber immersed in hydrogen peroxide became tacky, though the change occurred only in sunlight. According to Fickendey, moisture decreases the liability to tackiness by partially preventing the access of oxygen, while copper and iron salts accelerate the action.

Rubber becomes tacky if washed with, or immersed in, permanganate of potash; this is further evidence in support of the oxidation theory.

Moulds on Rubber

If kept for any length of time in a tropical climate, prepared rubber is likely to become mouldy. This is especially the case with biscuit and unsmoked sheet. Smoked sheet sometimes becomes mouldy, but crepe rubber is usually free from moulds.

The moulds in question are such as develop commonly in the Tropics on leather goods, damp paper, and miscellaneous vegetable substances such as bread, damp tea, copra, etc. They may be yellow or black (*Sterigmatocystis*) or green

(*Penicillium* and *Aspergillus*). Sheet rubber left lying in the laboratory for a long time develops patches of any or all of these.

An extensive series of observations made on the rubbers from various countries which were exhibited at the Ceylon Rubber Exhibition of 1906 showed that practically all of them became mouldy when left exposed for four months, with the exception of the "wild" rubbers. The freshly-cut surface of a Hard Para ball became green with mould; this is probably due to the amount of moisture contained in Hard Para, and it illustrates the fact that smoked rubber will soon become mouldy if imperfectly dried; an examination of any Hard Para ball will usually show that it has been mouldy at some time or other. Crepe rubber, as a rule, did not become mouldy, although it was kept in the same case with other rubbers which did.

The difference between crepe and sheet in this respect depends on the fact that the former is more thoroughly washed and dried. The drier the rubber the less possibility there is of its becoming mouldy. Moreover, these surface moulds live on the impurities in the rubber, and the washing and machining undergone by crepe rubber may remove these to a great extent. It is stated that sheet, prepared from dilute latex and well rolled, is not so liable to moulds as sheet prepared from a richer latex, or sheet not sufficiently rolled to express the contained moisture.

If dry sheet rubber is stacked, it will, if left long enough in a tropical climate, develop moulds on the exposed surfaces or edges. If, however, damp sheet is stacked, mould will develop between the sheets.

Estate complaints of the occurrence of mould generally relate to its development between the time of preparation and packing, or between the time of packing and its arrival at the market centre. In such cases the most general reason is that the rubber was insufficiently dried. To avoid moulds rubber should be dried as thoroughly and rapidly as possible.

Various methods have been proposed for cleaning mouldy rubber and preventing the further development of moulds, but none of them has been attended with much success. Brushing the sheets with five per cent solution of formalin, or with a one per cent solution of chinosol, is recommended in

Java. In that case the rubber should be well dried before being packed. A similar use of creosote has been found unsuccessful.

Potassium permanganate should not be used for disinfecting rubber. If used in any strength in which it is efficacious as a disinfectant, it will turn the rubber tacky, and in the strength usually recommended it is of no value whatever.

The method which appears to be as good as any of dealing with mouldy rubber is to rub off the mould with a dry cloth and to pack it as dry as possible. Whether moulds again develop is in all cases a matter of luck ; but rubber which has once been mouldy has lost some of the substances on which the moulds feed, and is in some degree less liable to develop moulds again if kept dry.

It may be noted that there is no evidence that the development of surface moulds affects the quality of the rubber.

The Effect of Bordeaux Mixture on Rubber

It is well established that the presence of copper salts, such as copper sulphate, or of particles of metallic copper, in prepared rubber induces tackiness. If rubber is washed with a solution of copper sulphate it becomes tacky, while if copper sulphate is added to the latex before coagulation, the resulting rubber changes into a resinous sticky mass when dry. Hence it is generally held that Bordeaux Mixture, which is the most efficacious fungicidal spray available for general use, cannot be employed in diseases of *Hevea*, because it is a copper compound, and if traces of it get into the latex the rubber will become tacky.

The experiments which have been carried out to test this point have, however, not been attended by any such result. At Peradeniya a row of twenty-five trees, tapped on alternate days, was well sprayed with Bordeaux Mixture. The trees were tapped with two cuts a foot apart on one-third the circumference, and the mixture was applied to the tapping surface to a height of three feet in such quantity that it ran along the cuts and down the vertical channel. Heavy rain fell five days after the spraying, and the rubber of that day's tapping, when analysed, showed 0·00016 per cent of copper in the

biscuit, and 0·003 per cent in the scrap. For six months from the date of spraying, the rubber, which was all prepared in biscuit form, was kept under observation, but no case of tackiness was observed. The experiment has been repeated with similar results in Java and Malaya.

The question of the employment of Bordeaux Mixture for diseases of rubber trees consequently remains open to further investigation. It is possible that the conflicting results obtained in the experiments quoted depend upon the state of the copper in Bordeaux Mixture, as opposed to that in copper sulphate. Before the adoption of Bordeaux Mixture can be recommended, research is required not only into its action on raw rubber, but also into the behaviour of the rubber during vulcanisation and manufacture.

CHAPTER VIII

PESTS

Mammals

All the common herbivorous mammals show a partiality for *Hevea brasiliensis.* Horses and cattle devour the foliage greedily, while goats, wild pigs, deer, and antelopes will strip off the bark from young trees. Hence a liberal use of barbed-wire fencing is generally necessary.

Elephants have done considerable damage in Malaya. They not only break off, or uproot, small trees, but, by the destruction of the fencing, open a way for deer and other animals. They are said to eat the roots of the rubber tree, particularly the tap root. Land which has been cleared and planted, and then allowed to lapse into weeds, is particularly liable to be invaded by elephants ; and they are also apt to frequent areas, now under Rubber, which were formerly their feeding grounds. As elephant-catching is not an established business in Malaya, that obvious method of reducing their numbers has not been employed.

Mr. B. H. F. Barnard has recorded a successful method of keeping elephants away from Rubber plantations in Malaya by a system of patrols. The number and size of the herds in the district, the seasons at which they visited feeding grounds in the vicinity of the plantations, and their usual routes of travel were ascertained as far as possible, and tracks were cut through the forest to enable the patrols to get about the country and keep in touch with the movements of the elephants. The patrols were unarmed, but were supplied with Chinese crackers and bombs, and with these any herd which appeared likely to enter an estate was driven back.

Porcupines have been one of the most serious pests of

young Rubber in Ceylon, and it has generally been customary to pay a fixed sum per head for all porcupines brought in, no matter where they were caught. The porcupine strips the bark off the stem from ground level to a height sometimes of two feet, and it may completely ring trees three or four years old. Various patent mixtures have been applied to the stems with the object of keeping off these destructive animals, but in no case have they proved successful, though it has been stated that a slight smear of Stockholm tar, not sufficient to penetrate the bark, will effect the desired result. But, in general, it has been found best to rely on the native trapper.

The bandicoot usually burrows along underground and attacks the roots or stems of plants below the surface, the first indication of the damage being the falling over of the plant. In the case of Rubber it has been found to attack young trees about an inch and a half in diameter by digging a hole at one side of the plant, and gnawing away the root as far as it can get. It has been suggested that the bandicoot fells the tree in order to get at the tender bark on the upper parts, but it is the bandicoot's habit to feed on roots, and, in general, it pays no attention to the fallen plant. As this animal usually feeds underground, it is impossible to protect the plants by the application of any mixture, and the native trapper must again be relied on.

Small rodents have been recorded to have been responsible for the destruction of a considerable acreage of young Rubber in Malaya shortly after planting with basket plants. The attacks were always in areas which afforded plenty of cover, *e.g.* roots, stumps, and unburnt timber, and the animals did not appear to go far into the open. Planting out strong stumps, or clearing the affected area of timber, etc., is recommended in such cases.

Insects

A large number of insects has been recorded as found on *Hevea* plants, but the only serious pests observed up to the present time are the White Ant (*Termes gestroi*), the Rubber Leaf Mite, the Root Borer (*Batocera rubus*), and, in Java, the Locust (*Cyrtacanthacris nigricornis*).

White Ants

The status of white ants, in their relation to the Rubber tree, differs enormously in the different rubber-growing countries. In Ceylon and South India the white ant is not a pest; in Malaya, Java, and Sumatra it is one of the worst pests with which the rubber planter has to deal. The explanation of this is simply that the species of white ant which attacks living trees generally, and has extended its ravages to the Rubber tree, viz. *Termes gestroi*, is not found in the former countries.

In Ceylon *Eutermes inanis* has been found, on one occasion, in the hollow stem of a Rubber tree. The tree had been broken off by the wind, and several secondary stems had sprung up from the original stump. The white ants had attacked the broken stem from the top, and had established a nest in the wood, but did not touch the outer living tissues. The nest was scooped out, and the insects were got rid of by flooding the cavity with a solution of naphthalene in petrol.

The common mound-building termites, *e.g.* *Termes redemanni* and *Termes obscuriceps*, often build a coating of earth over the bark, sometimes all round the tree and to a height of two or three feet. The insects feed beneath this covering, but they eat only the outer dead bark, and do not penetrate into the living cortex. Consequently they do not cause any direct damage. The coating of earth should be brushed off, a task which should be carried out by the tapping cooly. It has, however, been stated that Brown Bast is conveyed to the trees by white ants which devour the outer dead bark, and, if that is substantiated, it will be necessary to take steps to prevent them building this casing on the tree. That would entail the destruction of the white ant hills, and for that purpose the Universal White Ant Exterminator should be used. It is useless merely to level or dig up white ant nests, or to pay special rewards for queens. Some of the insects are of course destroyed if a nest is dug up, but ordinary observation will show that a large proportion are left,—quite sufficient to reconstruct it. The removal of the queen, no doubt, retards the increase of population for a short time, but the termites soon evolve a successor.

With the exception of the foregoing cases, white ants in Ceylon only attack Rubber trees which have previously been attacked by some fungus disease.

The conditions in Malaya, Java, and Sumatra are quite different. In those countries, and in Malaya especially, the termite fauna includes a species, *Termes* (*Coptotermes*) *gestroi*, which has long been known to attack living trees, and has unfortunately included *Hevea* among its victims. This species was discovered by Haviland in Malaya, and the fact that it attacked living trees was recorded by him, but it was not until Rubber estates were opened on a large scale that it became of economic importance.

Termes gestroi usually attacks a tree below ground level. Like the majority of termites, it travels underground by means of narrow galleries, and when one of these galleries happens to meet a root of a Rubber tree the insects attack it. Lateral roots may be immediately attacked, or the insects may tunnel a gallery underneath the lateral until the tap root is reached, into which they penetrate. Once inside the tap root, the termites eat out galleries in the wood and advance upwards into the stem. The wood of the tree is hollowed out, and the cavity is filled with a comb which is built of the excreta of the insects, and is, in fact, the remains of the wood of the tree after it has passed through their bodies. Ultimately the tap root is destroyed, the laterals hollowed out, and the interior of the stem becomes a termite nest. The affected trees may then blow over, or fall over during rainy weather owing to the extra weight of the wet foliage.

In wet weather *Termes gestroi* will appear on the Rubber tree above ground, and cover the trunk with a casing of mud for a height of several feet. Galleries are formed in the trunk immediately beneath the cortex, and passages from these extend through the bark to the exterior of the stem. On Kapok trees these passages are made from the exterior into the stem, but it appears to be undecided whether this occurs in *Hevea*. On the latter tree the termites have generally progressed within the tree higher than the mud casing extends on the outside, and on stripping the tree their galleries may be found in the wood immediately under unperforated bark. In *Hevea* this external occurrence of the termites is usually secondary, *i.e.* it will generally be found that when the mud

casing appears on the tree the roots have been attacked some time previously.

As the work of destruction is begun underground, and *Hevea* can suffer considerable damage to its roots without any ill effect on the crown, no general symptoms of an attack by *Termes gestroi* can be described. Hollow trees, trees with small holes in the trunk which exude latex, and the occurrence of the external mud casing, may all be signs of its presence, but none of these is universally so. The mud casing, as already noted, may be constructed by ordinary mound-building termites which eat only the dead outer bark. But the occurrence of any of these signs, in a country where *Termes gestroi* exists, should be regarded with suspicion, and the roots of the tree exposed and examined.

Like other species of termites, or white ants, the individuals of *Termes gestroi* constitute several different forms or castes. Those commonly found in the nests are workers, soldiers, and young. There is also, somewhere in the neighbourhood, a queen, with the usual abnormally distended abdomen, and a much smaller king, while at certain times the nests contain, in addition, winged insects. The latter are the males and females, the workers and soldiers being neuters. When the winged insects leave the nest, they set up fresh colonies elsewhere, if they escape the attacks of their numerous enemies.

The identification of the very numerous species of termites is not an easy matter, and to the ordinary layman they all look very much alike. It is based, in general, on the form of the soldier. There is no difficulty in determining which is the soldier, in the case of *Termes gestroi*, as it possesses a pair of strong mandibles, and if one puts his finger in the nest it will bite and remain attached. The mandibles are slender and red-brown, with black tips ; the head is oval and yellow-brown ; and the body white and somewhat parallel-sided. When the soldier bites, it exudes a drop of white milky fluid from an opening on the anterior part of the head. None of these points is peculiar to *Termes gestroi*, but they may serve to prevent confusion with some of the common harmless species.

The nests of *Termes gestroi* which are found in Rubber trees never contain queens or eggs. They are not the main

nests, but subsidiary nests. Hence it is of relatively little use to devote attention merely to the Rubber trees attacked, for that will leave the main nest untouched, and its inhabitants will invariably attack other trees. The principal nest, the one which contains the queen and eggs, is situated in some dead log in the neighbourhood, and from it galleries ramify underground to the subsidiary nests in the living trees. These galleries run at varying depths, according to the character of the soil, being, on flat alluvial land, usually one to two feet below the surface ; they are about a quarter of an inch high, and an inch broad, and are lined with a thin layer of some red substance.

The method of dealing with *Termes gestroi*, which was formerly proposed, was to follow up the underground runways or galleries from the tree attacked to the log in which the principal nest was situated, and then to destroy the termites in the log by fumigating with the Universal Ant Exterminator. That was subsequently modified in the following manner. The nest having been located in a log or stump, presumably by examination of all the logs in the neighbourhood, this was isolated by a trench, three feet from the log, cutting across all the run-ways. The trench was then left open for a few days, during which time the insects rebuilt galleries connecting the run-ways on either side of the trench. The log was then fumigated by boring auger holes in it and pumping in sulphur-arsenic fumes, and each run-way on the outer side of the trench was also fumigated. Finally the attacked trees were fumigated, if the fumes pumped into the run-ways had not already reached them.

The foregoing method failed to eradicate, or to stop the attacks of, *Termes gestroi*. It failed because it was a "piecemeal" method which did nothing to prevent attacks, and because it ignored facts of primary importance in the life history of the insect.

Termes gestroi does not live solely, or principally, on living trees. It feeds on dead wood just as well as on living wood. And its presence in a Rubber plantation is not due to any modern development on the part of the insect of a preference for *Hevea*, but to the abundance of dead timber and rotting stumps which are to be found there.

Both in Malaya and Java *Termes gestroi* is a comparatively rare insect in the jungle, where it inhabits dead or dying trees. Winged individuals from such localities, during their brief nuptial flight, reach a Rubber plantation, and settle down to found colonies in the rotting logs which so frequently abound there. In course of time these colonies produce other winged individuals, which establish new nests in other parts of the estate; and in a year or two numbers of colonies may be present before there is any evidence of their existence by attacks on the Rubber. Obviously, the only method of preventing this is the removal of all fallen timber and decaying stumps, *i.e.* the method of clean clearing. The piecemeal method of dealing with attacks as they arise loses sight of the fact that other logs are left which are capable of harbouring *Termes gestroi*; and even if every *Termes gestroi* was eradicated from an estate by that method, one pair of winged insects could re-infect the whole estate, as long as the timber remained.

Selective removal of timber has been advocated, those kinds being got rid of which are known to afford favourite nesting grounds for *Termes gestroi.* The number of such timbers is, however, fairly large, and there is no evidence that the termites will not inhabit any given timber if their more favoured kinds are wanting. The only safe plan is to remove and burn all timber.

The *Termes gestroi* question presents an exact parallel to the root disease problem. In both cases the attack on the Rubber tree proceeds from an external base of operations, and in both the external base is the same, viz. dead timber and decaying stumps. The solution is also the same in both—clean clearing.

Peaty land presents especial difficulties, both with regard to *Termes gestroi* and root disease fungi, owing to the existence of buried logs. These must also be got rid of, by probing for them, digging them up, and burning.

Where *Termes gestroi* has become established, particularly in old Rubber, fumigation methods should be employed, in addition to the destruction of all timber. All nests in logs or stumps should be destroyed by fumigating. Rubber trees which have been hollowed out by *Termes gestroi* should be treated by boring a hole into the trunk to reach the

hollow, inserting the nozzle of the fumigator, and luting it in with clay. After fumigation the hole should be plugged firmly with a cylinder of wood, the outer end of which should be left level with the cambium. It is, however, extremely doubtful whether such trees will survive very long.

Root and Stem Borer of *Heve* ⁝

The larva of a large longicorn beetle, *Batocera rubus*, has been found on several occasions boring into the tap root, or the lower part of the stem, of *Hevea* in Ceylon. It appears to be generally distributed through the rubber-growing areas of that country, and cases of its attack on *Hevea* are periodically reported, but it has not yet caused any widespread damage. According to the recorded instances, only a single tree is attacked in each case.

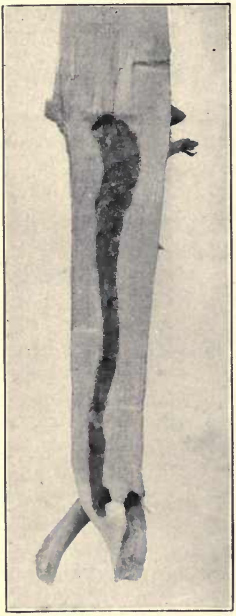


Fig. 36.—Root bored by *Batocera rubus*. $\times \frac{1}{5}$.

In the most general case the larva attacks the tap root well below ground, and bores a large gallery more or less up the centre (Fig. 36). The tree, if of moderate size, then behaves as though attacked by a root disease. The crown may become thin and the tree ultimately die. But most frequently the tree blows over, the root breaking off a few inches below ground. As a rule, only one larva is found in the tap root.

In other cases the tree is attacked at or near the collar. Cavities are then eaten under the bark and in the wood, or a gallery may be bored right into the heart of the tree. These attacks may be discovered by the rotting of the bark at the base of the tree, or by an exudation of yellowish matter.

In a number of recent cases the borer has been found

to attack the main stem of trees about twelve years old, above the tapping surface, from a height of about three or four feet to about seven or ten feet. The effect is then quite different from that of an attack on the root, the first sign, in the instances hitherto recorded, being the sudden death of all the leaves on the tree. Within two days the leaves curl and dry up, remaining attached to the twigs and retaining a pale green colour for a considerable time. The effect resembles that of a root disease, though the leaves do not turn brown readily, and the tree may be too large to be affected by a root disease in that particular way. The roots on examination are found to be quite healthy, and the stem appears normal. But on cutting into the stem it is found that the bark, though exhibiting no abnormal feature externally, is decayed internally, sometimes all round the stem, sometimes only in patches, for a length of three or four feet, from a short distance above the tapped surface sometimes as far as the first fork. The branches are not affected.

Under the decaying bark are found large white grubs in shallow cavities about the size of one's hand on the surface of the wood. From these cavities galleries penetrate into the centre of the stem. The grub appears to feed on the wood immediately beneath the bark, and eats out large areas, but to no great depth. The bark over these areas dies and decays, and this decay extends until adjacent patches coalesce and the tree is ringed. The death of the crown follows, as its water supply is cut off by the ringing and perforation of the stem.

The galleries in the stem are usually narrow and oval in section, with the longer axis vertical. They thus differ from the large gallery which the grub makes in the root. The explanation of the difference would appear to be that in the root the grub feeds on the wood in the centre and so enlarges its gallery, while in the stem it feeds beneath the bark, not in its gallery. In either case the gallery which the insect makes when it emerges is circular in section. Large numbers of grubs may be found in a single stem.

The larva (Plate VI., Fig. 2) is a large fat grub, up to three inches in length, creamy-white in colour, somewhat flattened above and below, segmented, and tapering from head to tail. Its head is triangular, dark brown or black,

and small, and is often partly retracted and more or less hidden by the border of the following segment.

The adult beetle is large and conspicuous (Plate VI., Fig. 1). In colour it is dull olive-brown, with reddish spots on the wing covers, which are also thickly covered on the anterior part with minute black spots. There is a small, white, shield-shaped patch at the junction of the wing covers, and a broad white band extending longitudinally along each side of the body. The antennae are long and stout, and swollen at the joints; they extend backwards beyond the extremity of the body. The average length of the beetle is nearly two inches.

The life history of the beetle, in its relation to the Rubber tree, has not yet been determined. It is assumed that the eggs are deposited in cavities or cracks in the bark, or in wounds, and that when the young larva hatches out it bores into the tree. But how it effects an entrance, eighteen inches or so below ground, is still obscure, the only suggestion hitherto made being that the larva fails to penetrate through healthy bark at the collar, and works its way down in the soil until it finds a diseased or broken lateral root. This, however, would seem to require that root attacks should be the exception, whereas they are actually the rule.

Green suggests that the normal mode of entry of the grub is through diseased bark, whether above or below ground. In many of the cases I have examined, however, the root has not been more decayed than it would be expected to be after having been tunnelled for several months. The grub has been found in roots attacked by Brown Root disease and *Ustulina*, but it also occurs in roots which are to all appearances sound. The attacks on the upper part of the stem have not been associated with any known disease.

The period taken by the larva to attain its full size has not been determined, but it is probably a lengthy one. Larvae have been kept under observation for five or six months, without any change in size being observed. On the other hand, the final stages of transformation are rapid, the change from larva to beetle occupying about a month. The damage to the Rubber tree is of course done during the extended larval period.

The larvae have been found in the roots of *Hevea* stumps

left in the ground after thinning out. These stumps, therefore, afford a breeding ground for the beetle.

The affected part of the stems of dead trees should be burnt at once. Until more is known about the mode of attack preventive measures cannot be devised.

Boring Beetles in General

The list of different species of boring beetles which have been found in dead stems of *Hevea* is a long one, but there is no doubt that, with few possible exceptions, these beetles have entered the stems after they were dead or diseased. Green, in 1914, enumerated twenty-three species, but, as far as the planter is concerned, only two of these can be said to be of importance, viz. *Xyleborus perforans* in Ceylon, and *Xyleborus parvulus* in Malaya.

The bore holes made through the bark and into the wood by these species of *Xyleborus* are of small size, about a millimetre (one-twenty-fifth of an inch) in diameter. They thus resemble the holes made by the Shot-hole borer of Tea, *Xyleborus fornicatus*, which attacks living Tea stems; and the beetles, to the layman, are very similar to the latter species. Hence their appearance in *Hevea* stems is liable to cause some alarm, seeing that they are so closely allied to a species which is a well-known pest of Tea.

Xyleborus perforans has long been known to attack diseased stems of cultivated plants in Ceylon. It bores into the canker patches on diseased Cacao stems, and it was at first considered to be the cause of the Cacao Canker. Similarly, it soon discovers and penetrates into patches of Claret-coloured Canker, which are caused by the same fungus, on *Hevea* stems. It appears to have a particular liking for bark which has been attacked by that disease. It also attacks stems killed by Die-back, and, sometimes, by Pink Disease, or green twigs which have died back from any cause. Scorched trees, especially if only lightly scorched, suffer severely from its attacks, and, frequently, the presence of the borer is the first visible sign that a tree has been injured by the fire. Trees which have been injured by others falling against them during the process of thinning out are also liable to be attacked on the bruised area.

Wood which has been exposed by tapping wounds is not usually attacked by *Xyleborus perforans*, but, on the other hand, wood exposed by cutting out canker patches very frequently is. Bark killed by Brown Bast does not appear to be attacked, except in cases where the disease extends to the wood, and then the stem may be riddled. After scraping for Brown Bast the exposed cortex appears only to be attacked if it dies back to the wood.

The action of *Xyleborus parvulus* in the Federated Malay States, according to the accounts given of it, is similar to that of *Xyleborus perforans*, but, in addition, it penetrates into *Hevea* stems through stubs left by bad pruning, or where branches have been broken off.

It would appear self-evident that no beetle can bore through the healthy laticiferous cortex of *Hevea* without causing latex to flow; and if latex exudes the insect must retreat or be smothered by it. Such penetration would only be possible if the beetle were furnished with some secretion which coagulated the latex in the latex vessels as it bored through them. That any of the borers known at present possess that power is more than doubtful, as cases have frequently been observed where beetles which attempted to enter a tree have become embedded in rubber in the hole. In attacks of Claret-coloured Canker, where the disease does not at first extend right through the cortex to the wood, borers will penetrate through the outer diseased layers, and may continue into the healthy tissue beneath, but they are then driven back by the exuding latex.

Attacks by borers on healthy bark are by no means unknown, but they are generally unsuccessful. In one instance, after thinning out, a large number of *Xyleborus perforans* hatched out from the felled Rubber logs and stumps, and these immediately attempted to enter the standing trees. They had apparently become accustomed to Rubber bark and wood. Another similar occurrence presented a peculiar feature for which no adequate explanation can be offered. The beetles in this case did not penetrate through the outer stone-cell layer of the cortex, and consequently were not hindered by a flow of latex, but, nevertheless, each one died in its hole with half its length projecting from the stem.

In general, *Xyleborus* only attacks *Hevea* when the bark is

diseased. There are, however, cases where these beetles do appear to have bored through healthy bark, and in such cases the apparent explanation is that the latex was, for some reason, stagnant, or unable to flow, at the time of attack. Overtapping has been suggested as a cause which would produce such an effect, but that would seem extremely doubtful. Moreover trees often cease to yield without any evident cause, and they are not necessarily then attacked by borers. Nor are they generally attacked when they cease to yield latex because of root disease. Further investigation is required on this point.

Bark which has been severely attacked and penetrated by borers should be cut out, and the exposed wood treated first with Solignum, or Jodelite, etc., and then tarred. Where exposed wood is attacked it should be dealt with in the same way. If only a few scattered holes are present in the bark each should be tarred over.

Bark-eating Caterpillars

Several species of caterpillars feed on the outer corky bark of *Hevea*, or on the lichens and algae which grow on it. As a rule, they do not penetrate into the living cortex and consequently do not cause any appreciable damage.

One of these weaves a small silk sheet, to which are fastened small fragments of bark and the excreta of the caterpillar. This sheet is attached flat to the bark, and the caterpillar lives and feeds beneath it. The mature insect is a small Tineid moth, *Comocritis pieria.*

Another Tineid caterpillar constructs a tube, about one-tenth of an inch in diameter, and up to four inches or so in length (Fig. 37). The tubes are formed of interwoven silk, and are covered on the outside with minute fragments of bark. At first sight the stem appears to be covered with short lengths of string. Each tube is fixed at one end in a crevice in the outer bark, but is free for the remainder of its length, and changes its position as the caterpillar, which is normally situated at the open end, moves over the bark. The caterpillar, in fact, browses over the bark like a cow at the end of a rope. This species has apparently not been identified.

The first of the above-mentioned caterpillars can be got rid of by simply brushing them off; but in the case of the second the tubes should be collected and destroyed as the caterpillars reascend the tree.

More serious damage has been caused in Malaya by a bark-eating caterpillar, which attacked both tapped and untapped bark and caused small irregular wounds. The caterpillar, which was not identified, was about one inch in length and one-tenth of an inch in breadth, brownish-red, each segment being provided with a pair of long, thick, clubbed hairs, standing out from the body and projecting downwards, so that when at rest it had the appearance of a small centipede. It was not, however, sufficiently numerous to warrant any method of treatment other than hand picking.

Fig. 37.—Tubes of a bark-eating caterpillar. × ¾.

In Sumatra it is recorded that caterpillars belonging to the group usually known as Bag worms, or Case worms, have attacked renewing bark about a month old, two and a half to three centimetres above the tapping cut, and have caused holes resembling neglected tapping wounds. The particular species concerned in this case was *Psyche* (*Acanthopsyche*) *snelleni*. It builds a conical house, about fifteen millimetres high, covered with minute fragments of bark (Plate VI., Fig. 3). As a rule this species feeds on the dead bark and lichens, but in the case recorded some of the caterpillars had extended their operations to living bark. The female insect does not leave its house, and the eggs are laid within the conical case. Consequently collection

and destruction of the cases destroys all the females and eggs.

Mites

The occurrence of mites on nursery plants of *Hevea* was first recorded by Arden in the Federated Malay States. Some years later it was again noted by Ridley and Derry in Singapore. The leaves of the seedlings became irregularly twisted and distorted, one side of the leaflet often being shorter than the other, and the leaflet curved to one side. On examining the under side of the leaf the tissue between the veins was seen to be swollen, the veins appearing green on a greyish background. The mites occurred on the under side of the leaf, but were not abundant. They were white, semi-transparent, with three brownish marks on the back.

The damage was confined to seedlings, especially those which for any reason were weak. Overcrowding in the nursery was said to be, in great part, a condition under which injury occurred. Frequently the lowest three or four leaves were attacked, after which the leaves which subsequently appeared developed normally. The mite was said to be rarely seen on well-grown adult trees, and it did not cause any injury on such.

Bernard recorded an attack by mites on nursery plants of *Hevea* in Java in 1907. The leaves were distorted, one side remaining normal and the other becoming somewhat shrivelled and crumpled with its margin curled underneath. The very young leaves did not develop, and the apex of the stem was swollen. The mite was white, about one-hundredth of an inch in length.

Bernard also recorded the attack of a different mite on trees eight years old. The effect on the young leaf was similar to that already described, while, when the leaves were older, their margins became dry and transparent. This attack occurred on trees which had wintered late, and whose new leaf, in consequence, developed during very dry weather.

More recently it has been recorded that on several estates in Java mites have caused a fall of young leaf immediately after wintering.

Richards states that, in the Federated Malay States, the Rubber leaf mite occurs on every estate, but it does not cause

serious injury unless the plants are growing under unfavourable conditions. The effect varies, from mere distortion of the leaves, to repeated defoliation, which finally results in the death of the plant. This variation depends on the virulence of the attack, the vigour of the plants, and soil and weather conditions.

The Rubber leaf mite usually attacks nursery plants, which may be checked and stunted, or even die, in consequence. When it attacks plants in young clearings they may become sickly, stunted, and misshapen, so that frequent supplying is necessary, while, in one instance, several hundred five-year-old trees were lost through exhaustion and die-back following an attack by these insects. It is capable, therefore, of becoming a serious pest under certain conditions.

The mites occur in large numbers on the under side of the leaves, where they feed by puncturing the epidermis and sucking out the cell sap. The life cycle of the mite is short, from five to seven days, and each female lays fifty or more eggs.

Mite attacks may be followed or accompanied by the attacks of stem and leaf fungi, notably *Helminthosporium*, *Gloeosporium*, *Phyllosticta*, and, later, *Diplodia*.

In Java removal and destruction of all the leaves attacked, or of the upper part of the stem, is said to have checked this pest in the case of nursery plants. Dusting the plants with flowers of sulphur has also been recommended.

In the Federated Malay States emphasis is laid on the improvement of soil conditions by draining, manuring, and cultivation. Where the attack is severe, spraying is necessary, and it has been found that a lime-sulphur wash containing two pounds of sulphur per 100 gallons gives satisfactory results. The plants should be sprayed twice, with an interval of ten days, and subsequently any nurseries or young plants which show signs of re-attack should be sprayed once in three or four weeks.

Locusts

In Ceylon the Spotted Locust (*Aularches militaris*) occasionally appears in swarms in some districts, and eats the leaves and gnaws the green stems of Dadaps. It has been reported to have attacked young Rubber in one instance, and

partially defoliated it, but injury to *Hevea* by these insects is practically unknown in that country.

In Malaya an outbreak of locusts (*Pachytylus* sp.) began in 1912, and has continued up to the present time (1919). They have not, however, attacked *Hevea*, though some damage has been caused through the breaking of the branches of that tree by the weight of the swarms of fliers which have a tendency to settle on Rubber trees at night. This species feeds chiefly on wild grasses, and consequently weedy estates afford them suitable feeding grounds.

More serious damage has been caused in Java by a locust, *Cyrtacanthacris nigricornis*, which, previously known to attack Coffee, turned its attention to *Hevea* about the year 1914. In 1915 it occurred in large swarms, and was still abundant in 1916, but the plague ceased in 1917. Teak forests formed its headquarters, and from these the winged insects spread to adjoining estates, attacking *Hevea*, *Castilloa*, *Ficus*, Dadap, Coffee, and Cacao. On estates bordering on the teak forests young *Hevea* was eaten bare, and stood leafless for some months. The twigs were not gnawed. Some plants were defoliated twice and died. Young plants especially were killed, while trees two to three years old produced a large number of weak branches after defoliation, and consequently an abnormal crown, which, however, could be improved by drastic pruning. The damage was greatest nearest the teak forests ; as the insects travelled further afield they scattered, and the injury then caused in any particular locality was small.

Locusts in the hopper stage can be combated by driving the swarms into pits, or bag traps, placed in their line of march, or by poisoning them by spraying the vegetation on which they are feeding with arsenite of soda. A solution which has been found efficacious in Malaya is one pound of arsenite of soda, dissolved in four gallons of water, with the addition of two pounds of molasses. Five cigarette tins of arsenite of soda are placed in a kerosene tin (4 gallons) full of water and boiled for ten minutes or a quarter of an hour. Ten cigarette tins of sugar, or molasses, are placed in another kerosene tin, which is then filled up with water. One-fifth of each of these solutions is poured through a strainer into a sprayer which will hold three gallons, and the sprayer then filled up with water. Vegetation sprayed with arsenite of

soda is poisonous, and precautions must be taken to prevent cattle, etc., feeding on it.

In the instances recorded the locusts which have attacked Rubber have been insects in the final or winged stage, not in the larval or hopper stage. In such cases the foregoing methods are inapplicable. Where the outbreak is small poisoned baits may be used, placed in heaps among the plants. Green recommends a bait made of one part Paris Green, two parts of salt, and forty parts of fresh horse dung, with sufficient water to make the mixture soft without being sloppy. The bait recommended for crickets (p. 245) may be used, if horse dung is unobtainable. But in a continued plague of locusts the insects should be attacked in the hopper stage.

Where locusts congregate on definite patches on cultivated land for the purpose of laying their eggs (which are laid in holes in the ground) they may be swept into bags and destroyed by sinking the bags in water. The ground should then be broken up to a depth of six inches, and quicklime forked in.

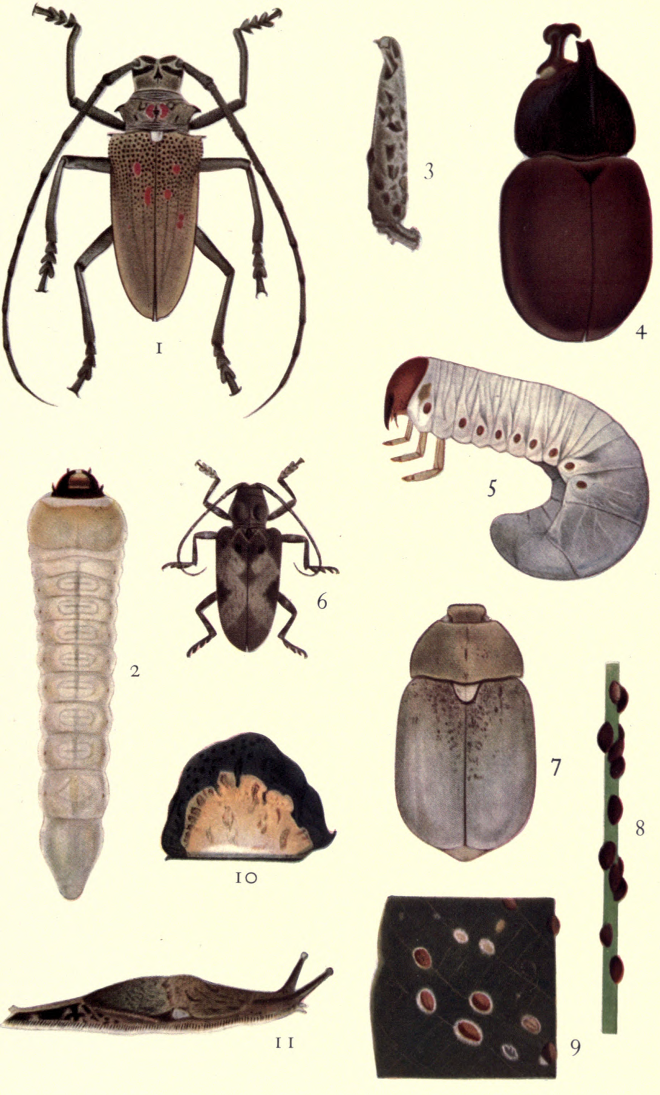
Scale Insects

Several species of scale insects have been found on *Hevea*, but few of them in any quantity; and up to the present no serious damage has been caused by them.

Green has recorded the occurrence of *Asterolecanium pustulans* on *Hevea* in Ceylon, and states that it is responsible for an unhealthy condition of the stem. The insects occupy small depressions in the bark, and, when present in considerable numbers, the bark assumes an unhealthy nodular and hidebound condition, and tapping may be interfered with. But this occurrence would appear to be very rare.

The scale insects commonly found on *Hevea* leaves and green stems are *Lecanium nigrum*, a purple-black convex species about one-fifth of an inch long (Plate VI., Fig. 8), and *Lecanium viride*, a somewhat flat green scale about the same length. They occur on the leaves, often congregated along the lines of the veins, or they may thickly encrust the terminal green stems. Attention is usually directed to their presence by the growth of the black "Sooty Moulds" over the leaves and stems (see p. 94).

PLATE VI.



PESTS OF HEVEA

It would scarcely be possible to treat these insects by spraying methods in the case of *Hevea*. Fortunately they are, as a rule, kept in check in Ceylon by parasitic fungi. One fungus, *Cephalosporium Lecanii*, attacks the commoner species and kills them, subsequently growing out as a white fringe round each scale (Plate VI., Fig. 9). Another fungus, *Hypocrella Reineckiana*, grows over each scale in a hard cushion-like mass, which is at first red-brown or yellow-brown, often with a glaucous bloom, but becomes black when old (Plate VI., Fig. 10). Both these fungi are parasitic only on the scale insects; they do not attack the tree. They should be left undisturbed when seen.

Ants

The red ant (*Oecophylla smaragdina*), though not a pest of the Rubber tree, can become a decided nuisance on a Rubber estate, so much so that coolies will refuse to work in fields heavily infested with them.

This well-known ant constructs its nest in the foliage of the tree by binding together living leaves, and if the nest is disturbed it attacks the aggressor and bites vigorously. It frequents the stem of the tree on which the nest is situated, and if present in large numbers may cause inconvenience to the tapping cooly. It is, however, when the trees are wintering that these ants make their presence (literally) felt to the utmost. The nests then fall to the ground when the leaves wither, and large areas may be covered with hordes of red ants, only too ready to attack any one who passes.

These ants may be got rid of by continually burning the nests.

Pests of Seedlings and Young Plants

Cockchafer Grubs

The grubs of various species of Cockchafers, or May Beetles, have been found to attack the roots of young *Hevea* plants, whether stumps or seedlings. These are, in general, large, white, fleshy grubs, wrinkled towards the head end,

but smooth towards the hinder part, which is generally swollen and curved round towards the head (Plate VI., Fig. 5). They are frequent in soil where vegetable matter has recently been buried, as, for instance, among Tea in the holes in which prunings have been buried, or on land formerly in grass, where the grass has been turned in. The eggs of the beetle are laid in soil of this character, and the grubs burrow underground to the roots of neighbouring plants.

In Malaya the roots of *Hevea* seedlings have been attacked by the grub of a cockchafer beetle allied to *Tricholepis lactea*. The grub is about two and a half inches long, creamy-white, shiny, slightly hairy. The adult beetle is about one and a half inches long, snowy-white, with rather darker stripes along the wing cases. Collection of the grubs and beetles for cash has been suggested as a means of getting rid of it.

In Ceylon the cockchafer grub which attacks the roots of young Rubber plants is usually the grub of *Lepidiota pinguis*. This was formerly known as a pest on Coffee estates, and does serious damage to Cinnamon. It also attacks Tea. The grub is of the usual shape and up to three inches in length. The beetle is rather more than two inches long, dull brown, with a covering of greyish hairs (Plate VI., Fig. 7). The beetle lays its eggs just below the surface of the ground, and the grubs burrow down and attack the roots of the plants. The tap roots of *Hevea* stumps have in some cases been eaten clean off up to within an inch of the surface of the soil, and in one instance three thousand plants were lost in one clearing, as many as five or six grubs being found in each hole. Older trees are apparently not attacked.

Nitrate of soda, applied at the rate of one to two ounces for each plant, is said to drive away the grubs. Vaporite has also been recommended, about one to one and a half ounces forked in about six inches away from the stem of the plant. With the latter substance the grubs are said to come to the surface, and crawl away or die. Vaporite should not come in direct contact with the roots. Dead plants should be dug up and search made for the grubs round them and neighbouring plants.

In Java a large number of plants a few months old

were killed in one clearing by cockchafer grubs (Oerets). The side roots were eaten off, the cortex of the tap root eaten away, and in some cases holes were gnawed in the wood. The species in this case was *Holotrichia leucophthalma*, a dark brown, or red-brown, shining beetle, about an inch in length. The colour is darkest on the head.

The attack occurred on *Hevea* interplanted with *Robusta* Coffee, in a clearing which was clean weeded, but had been badly burnt off. It was proved that the grub preferred *Hevea* to Coffee, but would attack many kinds of plants, and more particularly favoured succulent plants, including common weeds. Large numbers of grubs were found under decaying *Ficus* wood and rotting bamboo leaves. The beetle flies at night, and buries itself in the soil, to a depth of about four inches, during the day. In the instance recorded no beetles were found in the soil in the clearing infested by the grubs, but they occurred in a neighbouring field of old Coffee where the ground was shaded.

To avoid attacks of *Holotrichia leucophthalma* it is recommended that the ground should be cleared as far as possible of all decaying branches, leaves, logs, etc., before the time when the adult beetles begin to appear, so that possible breeding places are got rid of. In Java the beetles are found on the wing during the first months of the wet season, October to January. If a clearing is attacked the more succulent weeds should be allowed to grow, as the grubs will feed on these in preference to the *Hevea* ; it may be advisable to sow seeds of a succulent plant, *e.g. Amaranthus gangeticus*. Search should be made in the vicinity of the clearing for the places where the beetles hide during the day, and as many as possible should be caught, so that the pest may not spread to other clearings.

Bark-eating Beetles

A longicorn beetle, *Moechotypa verrucicollis*, is said to damage the stems of young *Hevea* trees, or of stumps shortly after planting out, by gnawing off the bark. The observations on this point, however, are not in entire agreement.

Green records that the injured stems showed irregular patches where the bark had been destroyed, in some cases

completely ringing the tree. No latex had exuded from the wounds; consequently the stems had been dry when attacked, and the roots showed the presence of the root disease fungus of Rubber stumps, viz. *Botryodiplodia Theobromae*. When the beetles were placed in a cage with a healthy young *Hevea*, one individual climbed up the stem and fixed its jaws in the tender bark; but when the latex exuded it abandoned the attack, and devoted itself to getting rid of the rubber adhering to it. After a week's confinement without other food the beetles still refused to touch the living bark.

Rutherford recorded a case in which the beetles had attacked stumps planted out a month previously, and noted that they had chiefly eaten the bark on plants which were not likely to grow, though they had also been found on healthy stumps. From his experiments he concluded that, while the beetles can undoubtedly eat the bark in spite of the flow of latex, they prefer dry bark.

The beetle is about an inch long, of a reddish-purple colour, with a greyish area in the form of an X on the wing covers (Plate VI., Fig. 6). The under surface is pinkish.

Rutherford recommended that the stumps attacked should be sprayed with Lead Arsenate.

Rhinoceros Beetles

The Fork-horned Rhinoceros Beetle, *Xylotrupes* sp. (Plate VI., Fig. 4), attacks stumps soon after planting out, as soon as the shoots appear. The young shoots are bitten off, and the process may be repeated as often as new shoots appear, until the plants are clubbed and worthless. Pratt records that he has seen 300 acres of Rubber, eighteen months old, without a single green leaf owing to the attack of this beetle, and that on another occasion 1000 acres suffered in the same way. The beetles rest during the day on old Rubber in the neighbourhood, or in jungle.

The attacks are prevented by enclosing each plant in a cylinder made of ordinary newspaper. A full sheet is rolled up into a cylinder the height of the paper and about six inches in diameter, and fastened with three pins. These

are placed over the stumps, and fixed in position by means of three thin stakes on the inside.

Swarming Caterpillars

Swarms of caterpillars, which had originally developed on grass, etc., have been found to pass on to Rubber after their original food had become exhausted. In the Federated Malay States an instance has been recorded where caterpillars (*Spodoptera* sp.) first of all developed in an area which had previously been flooded and was consequently covered with rank grass. The resulting moths laid their eggs in a neighbouring young clearing, planted with stumps and seed at stake. The next generation of caterpillars ate up all the available grass and weeds in the clearing, and then attacked the young Rubber, defoliating it in a few days, and gnawing the green stems, over an area of several acres.

Such an occurrence is not likely to happen except in young clearings. Where swarms of caterpillars appear among young Rubber, their food plants, grasses, etc., should be sprayed with some poison which will not damage the Rubber. But perhaps one ought to regard such occurrences as an argument in favour of clean weeding.

Crickets

Crickets often give trouble in nurseries by biting off the young plants one or two centimetres above the ground. These insects live in holes in the ground, where they remain during the day, emerging at night to attack the plants. The remains of the plants may be found in their burrows. Heavy rains drive them out of their holes, and it has been suggested that advantage should be taken of that circumstance to collect them, or the nurseries might, if possible, be flooded for a short time. Green recommends that dilute Phenyl should be poured down the burrows.

These insects may be killed by the use of poisoned baits. One such, recommended in Java, is made by chopping up young maize plants and mixing a little treacle and five grams of arsenic or Paris Green with each pound of the

chopped plant. This is then placed in small heaps in the nurseries. Bran may be used instead of chopped green material.

In the Federated Malay States a large cricket, *Brachytrupes achatinus*, saws through young plants, leaving a stump one to three inches high. Its attacks have been circumvented by surrounding the young plants with cylinders of paper, as described for the Fork-horned Rhinoceros beetle (p. 244).

Slugs

Early in the history of plantation Rubber in the East it was found that slugs ascended the tree and drank the latex, either as it ran down the tapping cut, or after it had collected in the cup. In Ceylon the species which acquired this habit is a brown slug, *Mariaella dussumieri*, while in Java a different species, *Parmarion reticulatus*, has adopted the same practice.

As long as these slugs confined themselves to drinking the latex their presence was disregarded. The chief result in the case of the Ceylon species was said to be a loss of scrap rubber. Keuchenius, however, has shown that where these slugs are abundant the loss of rubber, owing to their consumption of latex, may be fairly large. He calculates that if each slug drinks a cubic centimetre of latex per day, then ten thousand will cause a loss of 150 pounds of dry rubber per month; and he instances one case in which over 37,000 slugs were collected in a period of three weeks.

In young Rubber these slugs have caused great damage by an entirely different method of feeding. They climb up the stems during the night and eat off the terminal bud. New buds then develop, and these are in turn bitten off, until the plants assume the appearances shown in Fig 38, which is a photograph, nearly natural size, of the leading shoots of three plants after repeated attacks. On the shoot in the centre the apex is clubbed and consists of a number of arrested shoots, while lower down the stem the leaves have disappeared, and side-shoots, some of them similarly clubbed, have developed, though the stem was still green. The apices of the other two are similar, but each stem has developed several side-shoots; the tops of these side-

shoots have also been attacked, and on one of them buds have appeared lower down and are giving rise to branches.

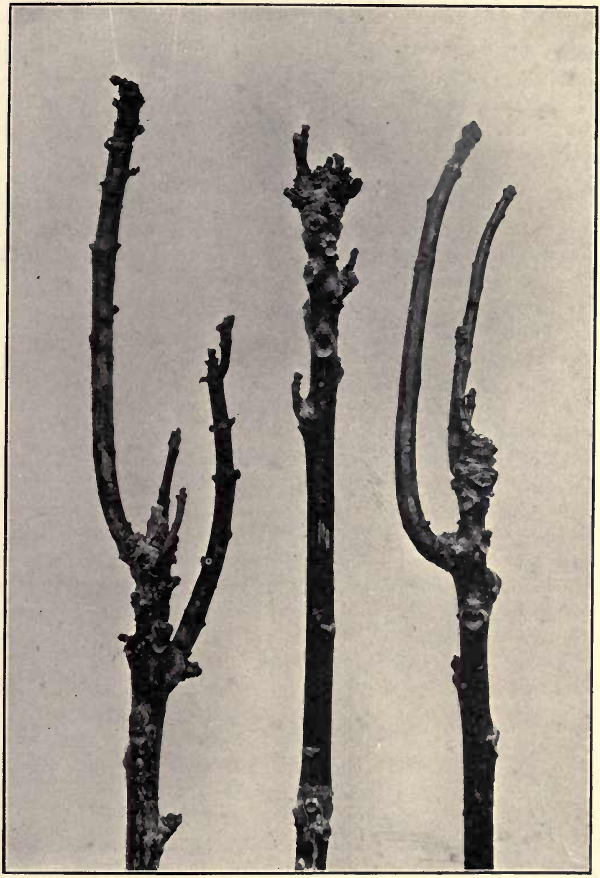


Fig. 38.—The effect of slugs.

Under normal conditions each of the leaders photographed would be a straight green stem, growing only at the apex ;

but in each case the apex has been converted into a cluster of short shoots, most of which have not been permitted to develop further, while on those which have temporarily escaped injury and grown for a short distance the same process is being repeated. This may be continued until the plant dies. In any case the damage is serious, as the development of the plants is arrested, and they may be so distorted as to be worthless.

These slugs feed chiefly at night. Hence they are not generally observed in the act, and the injury may be attributed to insects. During the day-time they may be found under dead leaves, etc., round the trees, or on the underside of living leaves on the tree itself. In Ceylon they were found climbing the stems in the evening. Plants which had branched were not severely attacked, those which suffered most being the single-stemmed trees; the latter, after wintering, were not permitted to come into leaf again, every fresh green shoot being nibbled off, and the green epidermis gnawed.

The slugs probably drink the latex because of the sugar which it contains; and they appear to attack the buds in order to obtain the latex.

Mariaella dussumieri is a yellowish-brown slug, mottled with darker dots and streaks. It is usually two or three inches long, but is said to grow to eight inches in India. The mantle, *i.e.* the fleshy fold which covers the middle of the body, bears two narrow ridges. Its minute shell is entirely hidden by the mantle. A figure of it is given on Plate VI., Fig. 11.

Parmarion reticulatus bears a small, thin, shield-like shell on the mantle.

Collection of the slugs has proved the most practicable method of dealing with this pest. Dead leaves, etc., should be raked away from the bases of the stems, and the field clean weeded. The heaps of dead leaves may be utilised as traps for the slugs. The latter may be killed by dropping them into a weak solution of Izal or some similar soluble disinfectant.

CHAPTER IX

MISCELLANEA

The Effect of Preservatives on Renewing Bark

In the operation of tapping, the dead bark, which is the natural protective layer of the tree, is removed, and the delicate inner tissue of the cortex exposed. The tree then immediately begins to form a cork cambium a short distance beneath the exposed surface, which cuts off the outer layers of cells as a new protective layer of dead brown bark. This bark layer is at first about 0·4 millimetre thick (about one-sixtieth of an inch), but its thickness is subsequently increased by the action of successive cork cambiums. In alternate-day tapping at Peradeniya this bark layer is completely formed about ten days after tapping, while its thickness is about 0·4 millimetre immediately above the cut, 0·7 millimetre one inch above, and up to 1·2 millimetre three inches above.

Any preservative or disinfectant applied to the renewing bark is liable to penetrate to a depth dependent upon the strength employed, and it may penetrate right through to the wood and cause wounds. Consequently, before using any of these substances it is necessary to make experiments to determine what amount of injury they can cause.

It would be expected that the area most liable to injury would be the zone immediately above the tapping cut which is not yet covered by a new bark layer. Any injury caused by the application of preservatives should, therefore, if it extends to the wood, be evident as a narrow wound parallel to the cut. Above that zone the cortex is protected by the dead bark layer, the thickness of which increases the further it is from the cut: and the substance applied must penetrate this bark layer, before it can attack the underlying living

tissues. Hence it would be anticipated that the further we ascend from the tapping cut the less is the probability of injury. In actual practice, however, conditions are somewhat different, because the outer brown layer cracks, and consequently renders the underlying tissues more accessible immediately beneath the crack. Hence it may happen that the penetration at a height of three inches from the cut, where the brown layer is usually cracked, may be greater than at points below that, until the actual cut is reached, though it may be confined to narrow lines corresponding with the cracks. But, owing to the greater thickness of the renewing bark, the risk of causing a wound at a distance from the tapping cut is less.

The possibility of injury, *i.e.* of wounding, depends also on the thickness of the layer of cortex left overlying the cambium after tapping. No wounding has been observed with the substances ordinarily in use where this layer was 1·5 millimetre thick.

The phenomena observed in the treated cortex may be summarised as follows: (1) The production of a network of shallow furrows on the surface of the living cortex, beneath the outer dead bark scale, indicating a deeper penetration through the cracks in the latter. (2) A blackening or browning of the tissues into which the liquid has penetrated; these tissues are killed and added to the dead bark scale. (3) A general greening of the living cortex in the majority of cases; this is a well-known characteristic of the action of tar products on plant tissues.

In the cases in which the penetration is greatest it is usually not uniform, *i.e.* not to the same depth, all the way down the tapping surface. Ordinary Brunolinum, for example, when used pure, may penetrate to a depth of one millimetre, three inches above the cut, but lower down the penetration becomes less and less until the actual cut is reached, when it again increases. It would appear that the extent of the penetration is dependent on the structure of the cortex. Under the dead bark scale the stone cell layer appears to be the more easily penetrated, the layer in which the latex tubes are continuous being untouched. Hence the penetration is deeper in the upper parts where the stone cell layer is thicker, and decreases downwards. On the tapping

cut, however, which was unprotected at the time of application, the penetration is again greater, and extends into the latex layer. Consequently, when a liquid penetrates deeply, a narrow depressed zone appears at the position occupied by the tapping cut at the time of application, and in a longitudinal section of the cortex the position of this zone is marked by a concavity or sinus.

It is this depression which should decide the question whether a given preservative is likely to cause injury. A penetration of a millimetre on the tapping cut, where the remaining cortex is only 1·5 millimetre thick, is likely to prove more serious than an equal penetration into renewing cortex, 3 millimetres thick, three inches or more above the tapping cut. The breadth of this zone varies with different preservatives, the maximum observed being 5 millimetres (one-fifth of an inch).

The details given below concerning different preservatives were obtained by experiments on trees tapped on alternate days by a single cut on one-third or one-quarter of the circumference. The thickness of the cortical layer left overlying the cambium was, in general, 1·5 millimetre. The application was made after the collection of the scrap on the day following the tapping. The extent of the penetration was determined by microscopical examination and measurement ten days after the application, tapping having been continued during the whole time. The renewed bark was in all cases normal, and no exudations of latex were caused. The phrase "no penetration at the tapping cut" means that the thickness of the scale formed over the most recently tapped zone after the application was not greater than that which is usually formed there, *i.e.* there was no extra bark formation due to the substance applied; the depth of penetration in such cases did not exceed 0·3 millimetre (one-eightieth of an inch).

Coal Tar and Tar Mixtures

Above the tapping cut coal tar does not penetrate through the dead bark, but where this is cracked it penetrates into the living cortex to a depth of 0·3 millimetre in narrow lines; hence the surface of the cortex is strongly furrowed. At the

tapping cut tar penetrates to a depth of 0·7 millimetre (one-thirty-fifth of an inch): there is a distinct sinus in the longitudinal section of the cortex when examined microscopically. Where a layer of cortex, 1·5 millimetre thick, is left overlying the cambium, tar will penetrate half-way through it at the tapping cut, but elsewhere the penetration is negligible.

A mixture of tar and tallow, in the proportion of 5 parts tar to 95 parts tallow, does not penetrate through the dead bark layer, and the surface of the underlying cortex is only slightly furrowed beneath the cracks. There is no penetration at the tapping cut.

Tallow has been largely replaced by liquid fuel, owing to the high cost of the former. Experiments with liquid fuel alone showed no penetration beyond the thickness of the normal bark layer, either above or at the tapping cut.

A mixture of 20 parts tar and 80 parts liquid fuel showed no penetration through the bark layer at a distance of an inch above the tapping cut, and no penetration beyond the normal thickness of the bark layer at the tapping cut.

A mixture of 80 parts tar and 20 parts liquid fuel showed no penetration through the dead bark layer one inch above the tapping cut, but at the cut the penetration extended to 0·8 millimetre, and there was a distinct sinus in the longitudinal section. The effect of this mixture is similar to that of pure coal tar.

From the foregoing results it would appear that the penetration of tar and liquid fuel mixtures at the tapping cut increases as the proportion of tar is increased. It may, however, be noted that liquid fuel is not necessarily of constant composition, and it is possible that different samples may vary in their action on renewing bark.

Tar and tar mixtures have been applied to renewing bark as a general protective against Black Thread and other diseases. But, in general, they have been applied at long intervals, say once a month, and in that case the part most liable to infection is left unprotected between the periodic applications. It is urged that they cannot be applied after every tapping, because they take longer to apply than the more fluid preservatives, and they may clog the tapping knife at the next tapping, and so lead to an undue consumption of bark and perhaps contamination of the latex. A mixture of

20 per cent tar and 80 per cent liquid fuel has, however, been used on one estate for over two years, and is applied twice a week; and from Java it has been reported that pure coal tar has been applied regularly after every tapping. But for regular preventive painting against Black Thread the weaker solutions of Brunolinum, etc., are more easily applied.

In experiments carried out at Peradeniya with tar and tar mixtures no exudation of latex was caused. Such exudation does, however, occur on estates. In one instance it followed an application of 10 per cent tar and 90 per cent liquid fuel, and in another an application of 40 per cent tar and 60 per cent tallow. This exudation of latex may occur up to a height of four inches above the tapping cut. It frequently takes place at the edge of small tapping wounds, but it also occurs from unwounded cortex. No injury appears to follow this, and it is generally regarded as negligible.

Tar and tar mixtures are often applied too thickly. All that is required is the thinnest possible smear. It should not be so thick that it melts and runs down to the cut.

When tar and tar mixtures are applied to patches attacked by Claret-coloured Canker, without first excising the diseased bark, the disease continues under the tar layer. That fact was well known when Cacao Canker first became prominent, and it was that which led to the universal condemnation of tar in Ceylon. Not only does the disease flourish beneath the tar, but the protective covering hinders the drying out of the canker which should occur in the dry weather. Tar or tar mixtures may be applied to canker patches after the cankered bark has been excised, but if efficient supervision cannot be exercised, it is better to use Brunolinum, Jodelite, etc., as scamped work is then more easily detected.

Old wounds which extend to the wood should be tarred periodically, say once a year. Tar and tallow does not prevent beetles boring into the exposed wood, especially on recent canker wounds. Where beetles bore through into tarred wood, wounds should first of all be painted with Solignum, or Brunolinum, etc., and tarred when that is dry.

Brunolinum

The original Brunolinum (ordinary Brunolinum) was not miscible with water alone, but required the addition of soft soap. This has now been replaced by Brunolinum Plantarium, which mixes with water without any addition. The latter should be used, as it involves less trouble in mixing.

Ordinary Brunolinum, used at full strength, penetrates through the dead bark and into the living cortex to a depth of a millimetre, when applied to the renewing bark three inches above the tapping cut. It penetrates through the stone cell layer, but in the trees examined it did not enter the layer in which the latex tubes are continuous. Half an inch above the cut the penetration was only 0·3 millimetre, while at the cut it was increased only to 0·4 millimetre and there was no well-marked sinus.

Ordinary Brunolinum, 20 per cent. This mixture does not penetrate, except through the cracks in the dead bark, and there the penetration only amounts to 0·2 millimetre into the living cortex.

Ordinary Brunolinum, 5 per cent. No penetration was observed with this mixture.

Brunolinum Plantarium, undiluted, penetrates through the dead bark scale and into the living cortex to a depth of 0·5 millimetre at a height of one inch above the cut. Where the bark layer has cracked and separated from the cortex, so that the liquid can collect behind it, the penetration may amount to 0·8 millimetre. At the tapping cut the penetration was 0·6 millimetre, with a well-defined sinus.

Brunolinum Plantarium, 20 per cent. This mixture showed no penetration through the dead bark layer and no sinus at the cut.

Brunolinum Plantarium, 5 per cent. This showed no penetration.

Tests with "double strength" Brunolinum Plantarium did not show any marked differences in result from the preceding.

Brunolinum and Brunolinum Plantarium are not recommended for application in undiluted form to *Hevea* bark except in special cases. For example, after scraping for Canker or Brown Bast, the application of the undiluted

liquid may be advantageous, as it will kill off a thin layer of the remaining cortex and so destroy any diseased tissue which may have been left. But they should not be used undiluted for regularly repeated applications.

The 20 per cent solution of Brunolinum, or Brunolinum Plantarium, is used to cure Black Thread. It should be applied to diseased trees as soon as the disease begins, and the application repeated every three days for six applications. It is to be noted that this is a treatment to be adopted when the disease is active, *i.e.* when the decay is progressing and the wounds, or patches of diseased bark, are gradually growing larger.

The 5 per cent solution of Brunolinum, or Brunolinum Plantarium, is used in preventive painting, *i.e.* to prevent the attack of Black Thread. For that purpose it must be applied after every tapping during the rainy season.

Carbolineum Plantarium

Carbolineum Plantarium, undiluted, has a penetration similar to that of ordinary Brunolinum. At three inches above the tapping cut it penetrated through the dead bark and into the cortex to a depth of 1·5 millimetre. Lower down the penetration was less, but at the tapping cut it increased to a depth of 0·8 millimetre, and there was a well-defined sinus up to 5 millimetres broad.

Carbolineum Plantarium, 20 per cent, showed no penetration.

The remarks on the uses of Brunolinum Plantarium apply equally to Carbolineum Plantarium.

Jodelite

The penetration of Jodelite, undiluted, is similar to that of ordinary Brunolinum. One inch above the cut the penetration was 0·6 millimetre. It diminished below, but increased again at the cut to 0·5 millimetre, with a sinus 1·5 millimetre broad.

No penetration was observed with the 20 per cent solution, except to a slight depth through the cracks in the dead bark layer, producing shallow furrows on the surface of the cortex.

This substance can be used for the same purposes as Brunolinum.

Agrisol (*Soluble Solignum*)

Agrisol, applied undiluted, penetrated at the tapping cut to a depth of 0·6 millimetre; its penetration is therefore equal to that of Brunolinum Plantarium. In 20 per cent solution it penetrated slightly deeper than 20 per cent Brunolinum Plantarium, the depth being 0·3 millimetre for the former and 0·2 millimetre for the latter when tested at the same time.

This substance can be used for the same purposes as Brunolinum Plantarium.

Izal

A 20 per cent solution of Izal did not penetrate through the dead bark layer one inch above the cut, but at the cut it penetrated to a depth of 0·8 millimetre. The penetration of 20 per cent Izal at the cut is consequently as great as that of undiluted Carbolineum Plantarium, and it is not safe for continuous use.

Solignum

This has been used in 5 per cent and 20 per cent solution for Black Thread.

Solignum is also recommended for painting exposed wood before tarring it; this treatment is said to prevent the attacks of boring beetles.

Jeyes' Fluid

This has been used in 20 per cent solution to cure Black Thread. If employed for preventive painting it should not be less than 10 per cent. Creoline is similar to Jeyes' Fluid; it has been used in 5 per cent solution for preventive painting.

Percentage Solutions

20 per cent = 1 gallon to 4 gallons of water.
10 per cent = 1 gallon to 9 gallons of water.
5 per cent = 1 gallon to 19 gallons of water.
$2\frac{1}{2}$ per cent = 1 gallon to 39 gallons of water.

Brunolinum Plantarium, Carbolineum Plantarium, Agrisol, and Izal mix with water. Ordinary Brunolinum, Jodelite, and Solignum do not. In making solutions of the latter, 1 lb. of soft soap must be added for each gallon of the preservative.

Lime-sulphur Solution

Various recipes for preparing Lime-sulphur solution are in use, one of which is as follows:

Slake 4 lbs. of quicklime and put it in an iron drum or boiler with about 6 gallons of water. The boiler should be capable of holding about 12 gallons and should be marked inside at the 10-gallon level. Boil the lime and water mixture, and when boiling add 4½ lbs. of sulphur gradually, stirring the mixture all the time. When all the sulphur has been added, pour in *boiling* water to bring the level up to the 10-gallon mark, and boil for an hour longer, keeping the total volume at 10 gallons by adding *boiling* water. When cool this forms the stock solution. For spraying foliage it should be diluted to a strength of 2 lbs. of sulphur per 100 gallons, *i.e.* it should be diluted to 22½ times its volume.

Flowers of sulphur must be used in preparing this solution. If it is desired to keep the stock solution for some time it should be stored in full, air-tight vessels. Lime-sulphur solution must not be stored in copper vessels, nor used for spraying from copper sprayers. After being used with this solution all sprayers should be thoroughly washed out and cleaned.

Bordeaux Mixture

Bordeaux mixture is made by mixing together a solution of copper sulphate and milk of lime. Different proportions have been recommended from time to time, but it is now usual to take equal quantities of lime and copper sulphate. 5 lbs. of lime and 5 lbs. of copper sulphate in 50 gallons of water may be used. This gives a nominal excess of lime, which is an advantage in countries where lime is generally very impure.

The milk of lime and the copper sulphate solution must be made separately and then mixed. It was formerly advised that each should be made up to 25 gallons before

mixing, and the two then poured simultaneously into a third receptacle, but according to the Woburn authorities that is unnecessary, and better results are obtained by pouring a strong copper solution into the milk of lime.

The amount of copper sulphate which will dissolve in water depends upon the temperature. Roughly, at 50° F., 100 parts of water will dissolve 36 parts of copper sulphate, while at 70° F. 100 parts of water dissolve 40 parts of copper sulphate. As a gallon of water weighs 10 lbs., 10 gallons of water will dissolve 36 lbs. of copper sulphate at 50° F., and 40 lbs. at 70° F. But in making strong solutions allowance must be made for the lowest temperature to which the solution will be subjected, otherwise some of the copper sulphate will crystallise out as the solution cools. In practice it is not advisable to try to work too near the actual limits. If stock solutions of copper sulphate are made, they should not contain more than 2 or $2\frac{1}{2}$ lbs. to the gallon.

In preparing Bordeaux mixture, dissolve the 5 lbs. of copper sulphate in 5 gallons of water. The easiest way is to tie up the copper sulphate in a piece of sacking and suspend it at the top of a tub of water. The receptacle must not be made of iron or zinc. This solution should be begun the day before it is required.

Put 5 lbs. of quicklime into a bucket, and slake it by sprinkling it with a little water and leaving it for about half-an-hour or so to crumble down. Then mix it with more water so as to form a cream or milk, and finally pour it into a tub, adding water to make the quantity up to 45 gallons. This may also be done the day before using; the lime water deteriorates slightly owing to the absorption of carbon dioxide from the air, but if the liquid is undisturbed this action is confined to a surface film.

When required for use, stir up the 45 gallons of milk of lime, and pour into it the 5 gallons of copper sulphate solution, stirring it just enough to secure complete mixing. This final mixture must not be made in iron or zinc vessels; a wooden receptacle is the best. Very little stirring is required after the final mixing.

If the sprayers are not provided with strainers, the mixture must be poured into them through a strainer which will remove any particles of sand, etc., which might block

the tubes. It must be remembered that the fungicidal substance is the bluish-white precipitate which is suspended in the liquid, not the clear liquid which remains after the precipitate has settled.

It is customary to give tests to determine whether all the copper has combined with the lime, or whether any copper remains in solution. With the quantity of lime stated above, it is very improbable that any dissolved copper will be left. If, however, it is desired to test the mixture, the following method should be adopted. Put a few drops of a solution of potassium ferrocyanide into a white saucer with some water, and drop into this some of the clear liquid obtained after the Bordeaux mixture has been allowed to settle. If a brown or red coloration appears there is some copper left in solution. More milk of lime must then be added to the Bordeaux mixture, and the test repeated.

Woburn Bordeaux

Recent researches at the Woburn Experimental Fruit Farm have led to the recommendation of the following modified Bordeaux mixture, known as Woburn Bordeaux. With this mixture much less copper is required, and clear lime water is used instead of milk of lime. The quantities required are 1 lb. of copper sulphate to 13½ gallons of clear lime water, with the addition of soft water sufficient to bring the whole to 76 gallons.

Dissolve 1 lb. of copper sulphate, as directed above, in a gallon of water. Slake about a pound of quicklime, and put it in a tub with about 30 gallons of water; stir up the mixture two or three times and leave it to settle until the liquid becomes quite clear. The clear liquid contains lime in solution and is lime water. Run off 13½ gallons of the *clear lime water*, and mix it with the copper sulphate, not in an iron vessel. Finally, add soft water to bring the whole mixture up to 76 gallons. As the lime in this preparation is reduced to the minimum, the liquid should be tested by the ferrocyanide method, and if the test shows that some copper still remains in solution more lime water must be added.

The advantages of the Woburn Bordeaux are: (1) It

requires a smaller quantity of copper sulphate and is therefore cheaper; (2) lime water is used instead of milk of lime, and, with the poor quality of lime which alone is available in many districts, the former is more easily obtained in a satisfactory strength.

If soft water is not procurable, hard water may be softened by adding lime water to it. Water in a chalk district may be softened by adding about 26 fluid ounces of lime water to every 10 gallons, and even in the case of soft water, or rain-water, 4 or 5 fluid ounces of lime water may with advantage be added to every 10 gallons to remove the carbon dioxide in it. This should be done before adding the water to the copper sulphate-lime water mixture.

The preparation of these spray fluids is no doubt a troublesome process, but it is within the capacity of the average dispenser. Attempts have been made to avoid all the trouble by manufacturing a paste which has merely to be mixed with water before using, and these have been successful, as far as temperate countries are concerned. But these pastes invariably decompose under tropical conditions, and up to the present no method of overcoming that appears to have been discovered.

CHAPTER X

FUNGI ON *HEVEA*

THE following technical descriptions of the fungi which have been referred to in connection with the diseases of *Hevea* are included here for convenience of reference.

HYMENOMYCETAE

Marasmius equicrinis, Mull.—Pileus up to 8 mm. diameter, hemispherical, umbilicate, deeply radially sulcate, somewhat membranous, yellow-brown, red-brown, or ochraceous, with a minute black umbo at the base of the umbilicus; gills distant, five to eight, white then cream-coloured, broad, attenuated behind, united into a collar round the stalk; stalk black, shining, up to 2 cm. high, 0·25 mm. diameter, insititious, or arising from black, shining, rhizomorphic mycelium; spores white, narrow-oval, inequilateral, or clavate, $10\text{-}14 \times 4\ \mu$.

Fomes lignosus, Klotzsch.—Woody, imbricated, sometimes perennial; pileus dimidiate, usually about 10×6 cms., often larger, orbicular, at first red-brown with a yellow margin, becoming pale yellow-brown, with concentric red-brown lines, smooth, feebly sulcate, faintly radially striate and silky; thickness (with two pore layers) 1-1·5 cm.; pore surface at first orange, becoming red-brown; pores minute, 0·06-0·12 mm. diameter, 2·5-3·5 mm. long; context white, pores red-brown in section.

Fomes lamaoensis, Murrill.—Applanate, rather thin, hard, frequently concentrically grooved, purple-brown, glabrous, with a hard outer crust; internally yellow-brown, often with concentric growth zones, composed of two kinds of hyphae, the one thin-walled, the other thick-walled and resembling the setae. Pore surface dark brown or purple-brown; pores minute; setae numerous, obtuse.

Fomes pseudo-ferreus, Wakefield.—Pileus sessile, dimidiate, ungulate, or irregularly undulato-applanate, sometimes imbricate, glabrous, not zoned, with a rigid crust which cracks when dry, ferruginous becoming dark brown, the sterile margin whitish and swollen. Context floccose, cinnamon becoming brown. Tubes concolorous with the context,

whitish within. Pores minute, rounded, thick-walled, whitish, becoming yellow when bruised.

Poria hypobrunnea, Petch.—Effused, at first pale ochraceous, then pinkish-red, becoming brownish-red, and finally slate-coloured; margin at first white, tomentose. Basal layer blackish-brown, stout and compact when developed on a level surface, but loose and woolly when on an irregular surface or on soil, etc. Thickness of the compact form about 1·5 mm. Pores small, 0·1 mm. diameter.

Corticium salmonicolor, B. and Br.—Membranous, effused, rose-pink, or ochraceous, inseparable from the substratum, waxy when moist, finally cracked and areolated; basidia clavate, tetrasporous; sterigmata slender, 4-6 μ long; spores pyriform, hyaline, apiculate, 9-12 × 6-7 μ.

Cyphella Heveae, Massee.—Cups minute, 0·5 mm. diameter, scattered or gregarious, sessile, cup-shaped and expanded when moist, contracted and subglobose when dry, externally minutely pulverulent, honey-coloured; hymenium smooth, pinkish-white; spores elliptical, hyaline, 7-8 × 5 μ.

Phycomycetae

Phytophthora Faberi, Maubl.—Mycelium richly branched, inter- and intracellular, aseptate in the early stages, becoming septate later. Sporangiophores sympodially branched, bearing up to twenty sporangia or more. Sporangia ovate, or elongated ovate, 26-90 × 18-37 μ, average 50 × 28 μ; spherical resting conidia 23-50 μ diameter.

Phytophthora Meadii, McRae.—Mycelium branched, at first continuous, then septate; hyphae 3-6 to 10 μ diameter, inter- and intracellular. Sporangiophores branched, 10-200 μ long, but sometimes short; sporangia obpyriform but variable, terminal or lateral, on the fruits 33-67 × 14-28 μ, in water 20-44 × 16-29 μ; zoospores ovate or ellipsoid, biciliate, cilia 16-26 μ long, spores globose, 7-10 μ; oogonia pyriform, hyaline, smooth or rugose, on the fruits 20-48 × 20-40 μ, in culture 22-49 × 20-45 μ; antheridia persistent, hyaline, circular or ovoid, smooth, 8-16 × 10-16 μ, surrounding the base of the oogonium and part of the oogoniophore; oospores spherical, on the fruits 18-28 × 18-26 μ, in cultures 16-32 × 15-32 μ, wall 2-4 μ thick, yellow or yellow-brown, smooth.

Pyrenomycetae

Meliola Heveae, Vincens.—Mycelium scanty, forming small patches about 2 mm. diameter, dichotomously branched, 7-9 μ diameter, closely septate, constricted at the septa. Perithecia globose, up to 250 μ diameter, black; asci elliptic, two-spored, 60-70 × 40-50 μ; spores brown, narrow-oval, four-septate, constricted at the septa, 45-50 × 16-18 μ; setae brown, rigid, abruptly inflated at the base, 60-55 × 9-12 μ. On leaves of *Hevea brasiliensis*, Para.

Chaetopeltopsis tenuissima (Petch), Theiss. = *Asterina tenuissima*, Petch.—Extremely thin, forming a blackish discoloration on branches and fruits of *Hevea*, spreading indefinitely. Mycelial hyphae brown, 4-5 μ diameter, smooth, united by a hyaline film when old, bearing numerous septate, erect setae, 90-100 μ long, olivaceous, with acute tips. Perithecia flattened, black, 130-160 μ diameter, ostiolate; asci clavate, $30\text{-}40 \times 9\text{-}12$ μ; spores one-septate, fusoid, constricted at the septum, hyaline, 13×4 μ.

Guignardia Heveae, Syd.—Affected areas marginal, pale brown, with a purple-brown border. Perithecia epiphyllous, scattered, immersed, black, 0·2 mm. diameter; perithecial wall brown; ostiolum minute, not projecting; asci clavate, eight-spored, scarcely pedicellate, 60×10 μ; spores hyaline, narrow-oval or subcymbiform, ends obtuse, $12\text{-}16 \times 5\text{-}6$ μ. On leaves of *Hevea brasiliensis.*

Sphaerella Heveae, Petch.—Affected area marginal, yellow-brown, becoming grey, with a purple-brown margin. Perithecia gregarious, subepidermal, slightly elevated, black, 60-70 μ diameter; asci clavate, 30×6 μ; spores subfusoid or narrow-oval, ends rounded, one-septate, slightly constricted, the upper cell the larger, $9\text{-}10 \times 2{\cdot}5$ μ. On leaves of *Hevea brasiliensis.*

Nummularia pithodes (B. and Br.), Petch.—Widely effused, up to 30 cms. long and 15 cms. broad, or confluent for a length of several metres on erect or fallen tree trunks; developing in the cortex and forcing off the outer layers; adnate, flattened, 2-3 mm. thick, distinctly margined by the cortex, carbonaceous, black, dull, or sometimes shining, here and there slightly undulating but usually plane, smooth, or minutely papillate. Perithecia densely crowded, vertically elongated, 0·5 mm. diameter, 1·5 mm. high, ostiola usually not projecting; spores dark brown, broadly cymbiform, or fusoid-elliptic, inequilateral, $25\text{-}35 \times 9\text{-}11$ μ.

Ustulina zonata, Lév. — Stroma effused, undulating, centrally attached, often concentrically zoned, thin, several centimetres in diameter; at first white, bearing crowded, simple conidiophores in a continuous stratum, with narrow-oval, hyaline conidia, $6\text{-}8 \times 2\text{-}3$ μ; becoming greenish, then purple-grey, dotted with black ostiola, finally black and brittle. Perithecia globose, about 1 mm. diameter, distant, ostiola scarcely projecting; asci cylindric, long-stalked, eight-spored, 250×10 μ; spores black-brown, cymbiform, ends obtuse, $30\text{-}38 \times 9\text{-}13$ μ.

Eutypa caulivora, Massee = *Nummularia pithodes* (B. and Br.).

Diaporthe Heveae, Petch.—Perithecia distinct, black, 0·5-1 mm. diameter, in small groups, embedded in the wood; ostiolum about 0·1 mm. diameter, up to 0·5 mm. long, slightly projecting; asci $40\text{-}45 \times 6\text{-}8$ μ, narrow-oval, eight-spored; spores obliquely uniseriate, hyaline, fusoid, one-septate, $10\text{-}13 \times 4$ μ. In branches of *Hevea brasiliensis*, Ceylon.

Catacauma Huberi (P. Henn.), Theiss. and Syd. = *Phyllachora*

Huberi, P. Henn.—Hypophyllous, on yellowish spots, rounded or irregularly flattened, 3-11 mm. diameter, black, ostiola wide; perithecia crowded; asci clavate, eight-spored, 50-65 × 16-20 μ, spores biseriate or obliquely uniseriate; spores ovoid or subfusoid, hyaline, 14-18 × 8-10 μ. On leaves of *Hevea brasiliensis*, Para, Amazon valley, etc.

Dothidella Ulei, P. Henn.—Stromata caespitose, erumpent, ovoid, black, rugulose, about 0·3-3 mm. diameter; perithecia few, ovoid; asci clavate, eight-spored, 50-80 × 10-16 μ, spores subdistichous; paraphyses present; spores oblongo-clavate, hyaline, one-septate, scarcely constricted, 13-20 μ. On leaves of *Hevea brasiliensis*, Amazon valley. According to Griffon and Maublanc, the stromata sometimes contain pycnidial cavities, with cylindric pycnospores, inflated at the ends, 4-5 μ long, on flask-shaped basidia. Conidial stage = *Fusicladium macrosporum*, Kuyper. Pycnidial stage = *Aposphaeria Ulei*, P. Henn.

Sphaerostilbe repens, B. and Br.—Conidiophores 2-8 mm. high, 0·5-1 mm. diameter; stalk red-brown, tomentose; head white, opaque, globose, 0·5-1 mm. diameter; conidia oval, apiculate at one end, or rounded at both ends, hyaline, 9-22 × 6-10 μ. Perithecia clustered, on a stroma, or on the conidiophores, dark red, slightly rough, conoid, about 0·6 mm. high, 0·4 mm. diameter; asci cylindric, apex thickened, eight-spored, 190-220 × 9 μ; ascospores pale brown to reddish-brown, oval, one-septate, slightly constricted, 19-21 × 8 μ. Mycelium red-brown, rhizomorphic.

Hypocrella Reineckiana, P. Henn. — Stromata hemispherical or pulvinate, up to 4 mm. diameter, moderately hard, at first pale yellow or buff, becoming fuscous or slate-coloured with a glaucous bloom, finally black, usually smooth, glabrous. Pycnidia scattered, flask-shaped, or lobed, or tubular; pycnospores fusoid, ends pointed, 6-10 × 1·5-2 μ. Perithecia scattered, flask-shaped, up to 0·3 mm. deep, 0·15 mm. diameter; asci 170-180 × 8 μ; part-spores cylindric, 6-8 × 1-1·5 μ.

Discomycetae

Monascus purpureus, Went.—Hyphae filiform, septate, sparingly branched, ultimately bearing conidia; sporangia globose, 30-75 μ diameter, frequently polysporous; sporidia angular, then globose, 5-6·5 μ diameter, purple; conidia catenulate, globose, then angular, often irregular, purple.

Deuteromycetae

Phyllosticta Heveae, Zimm.—On brown or white spots on the leaves, often extending from the tip. Pycnidia epiphyllous, crowded, subepidermal, erumpent, somewhat flattened, brown, black round the ostiolum, 80-150 μ diameter, 60 μ high; ostiolum 16 μ diameter; spores elliptic, ends acute, hyaline, sometimes biguttulate, 6-7 × 2·5 μ.

Phyllosticta ramicola, Petch.—Pycnidia 0·1-0·25 mm. diameter, black, subepidermal, crowded, slightly prominent, lenticular, 75-140 μ high; spores narrow-oval, ends acute, often biguttulate, greenish hyaline, 8-12 × 2-3 μ, issuing in a fine white tendril. On green stems of *Hevea brasiliensis*.

Phoma Heveae, Petch.—Pycnidia black, hemispherical, gregarious, immersed, slightly prominent, 0·1-0·2 mm. diameter; spores elliptic, hyaline, 4-5 × 2 μ. On branches of *Hevea brasiliensis*.

Aposphaeria Ulei, P. Henn.—Pycnidia black, carbonaceous, almost spherical or ovoid, erumpent, appearing completely superficial, scattered or crowded, papillate, about 120-160 μ diameter; spores cylindric or fusoid, straight or somewhat curved, hyaline, 6-10 × 0·8-1 μ, containing two or three small guttae. On leaves of *Hevea brasiliensis*, with *Dothidella Ulei* and *Catacauma Huberi*.

Aposphaeria Heveae, Petch. — Pycnidia globose with a conical ostiolum, or oval, black, minutely rugose, 0·15-0·2 mm. diameter, clustered in cracks in the cortex, arising from a thin, immersed, black stroma; wall stout, cellular; basidia simple, short, up to 12 μ long; spores narrow-oval, hyaline, continuous, thin-walled, 8-12 × 3-4 μ, a few broadly oval, 6 × 4 μ. In dead bark of *Hevea brasiliensis*, Ceylon.

Diplodia rapax, Massee = *Botryodiplodia Theobromae*, Pat.

Botryodiplodia Theobromae, Pat.—Pycnidia scattered or confluent, sometimes immersed in an erumpent stroma; pycnidia 0·25-0·4 mm. diameter; spores oval, fuliginous or blackish-brown, 25-35 × 14-15 μ, one-septate; paraphyses abundant, linear, 40-80 μ long.

Ascochyta Heveae, Petch.—Affected areas marginal, white, or brownish-white, with a narrow, red-brown border. Pycnidia immersed, ostiolate, not beaked, black, 60-100 μ diameter; spores oblong-oval, hyaline, one-septate, ends obtuse, 9-12 × 5 μ. On leaves of *Hevea brasiliensis*.

Gloeosporium alborubrum, Petch.—Acervuli 150-200 μ diameter, black at first, white or pink when ripe; spores oblong, ends rounded, straight or slightly curved, 15-20 × 3-4 μ, often issuing in thick, white, or pink tendrils.

Gloeosporium Heveae, Petch.—Acervuli pale brown, scattered, irregular, flattened, erumpent, 0·1-0·25 mm. diameter, amphigenous; spore mass pale brown; spores oblong, ends rounded, 12-17 × 2·5-5 μ; basidia 20-34 × 2 μ. On leaves of *Hevea brasiliensis*.

Colletotrichum Heveae, Petch. — Acervuli black, scattered, epiphyllous, 0·1-0·25 mm. diameter; setae obtuse, one or two septate, up to 90 μ long; spores oblong with rounded ends, hyaline, granular, 18-24 × 7·5-8 μ; basidia 20-30 × 6-7 μ, thickened upwards.

Pestalozzia palmarum, Cooke.—Acervuli erumpent, up to 0·2 mm. diameter; conidia fusoid, four-septate, the terminal cells hyaline, the other three fuliginous and sometimes inflated; apical setae three, up to 30 μ long; pedicel slender, 3-8 μ long; dimensions (without pedicel or setae) 20-30 × 5-11 μ, coloured part 13-19 × 5-11 μ.

Chromosporium crustaceum, Sharples.—Upon agar forming a thick black layer with a sparse greyish mycelium; conidia, or yeast-cells, at first forming yeast-like packets by continuous budding; hyphae arising later; conidia $5 \times 3\ \mu$. On crepe rubber, causing a black spot.

Trichoderma Koningi, Oud.—Tufts orbicular, woolly, at first white, then spotted with green, finally uniformly green or pale olive; hyphae hyaline, obscurely and remotely septate, branched; branches alternate or opposite, once or twice bi- or tri-furcate, bearing conidia at the apices; conidia almost hyaline, elliptic, $3\text{-}4 \times 2{\cdot}5\text{-}3\ \mu$, in green clusters, 8-10 μ diameter.

Penicillium maculans, Sharples.—Hyphae hyaline; conidiophores ?; sterigmata branched, 6-8·5 μ long; conidia globose, smooth, yellow to reddish-brown, 2 μ diameter; secondary conidia oval, $6\text{-}8 \times 4{\cdot}5\text{-}5\ \mu$, intercalary or terminal. On sheet rubber, forming a yellow discoloration.

Zygosporium paraense, Vincens.—Setae 30-50 μ high, 3-5 μ diameter at the base, attenuated upwards, brown, almost hyaline at the inflated apex, usually with one basidium at the base; basidia brown, 12-15 μ long, 6-8 μ broad, 4-6 μ thick, two-spored; conidia elliptic, slightly coloured, $7\text{-}9 \times 4\text{-}6\ \mu$. On leaves of *Hevea brasiliensis*, Para.

Passalora Heveae, Mass. = *Fusicladium macrosporum*, Kuyper.

Scolecotrichum Heveae, Vincens.—Conidiophores brown, rigid, 150-200 μ high, 6-8 μ diameter, inflated slightly at the base; conidia catenulate, continuous, irregularly oval. On leaves of *Hevea brasiliensis*, Para.

Fusicladium macrosporum, Kuyper.—Spots amphigenous, olivaceous, becoming grey in the centre; at first, 3-10 mm. diameter, then greater, irregular, with confluent multiseptate hyphae forming a pseudostroma on old spots; conidiophores erumpent, unicellular, sometimes uniseptate, subglobose at the base, 40-70 μ high, 4-7 μ diameter, brown, often flexuose; conidia acrogenous, ellipsoid, ends obtuse, or obclavate-pyriform, irregular, $30\text{-}55 \times 8\text{-}12\ \mu$, finally uniseptate, scarcely constricted, dark brown.

Spondylocladium maculans, Bancroft.—Hyphae septate, dark, 3-4 μ diameter; conidiophores dark brown, nodular, 100-190 μ high, 6 μ diameter; conidia produced in whorls at the septa, up to six in a whorl, barrel-shaped, three-septate, constricted at the two outer septa, middle cells dark brown, terminal cells paler, $23\text{-}25 \times 11\text{-}14\ \mu$. On crepe rubber.

Helminthosporium Heveae, Petch.—Spots circular, 1-5 mm. diameter, surrounded by a purple-brown line; conidiophores scattered, simple, olivaceous, 80-200 μ long; conidia cymbiform, eight to eleven septate, brown, dark brown and shining by reflected light, $100\text{-}200 \times 15\text{-}18\ \mu$.

Cercospora Heveae, Vincens.—Conidiophores hypophyllous, clustered, arising from a minute stroma, irregular, geniculate, 20-25 μ high, 3-5 μ diameter; conidia narrow-oval or fusiform, 25-50 μ long, 3-5 μ

diameter, two to five septate, usually four-septate. On leaves of *Hevea brasiliensis*, with *Catacauma Huberi*, Para.

Fusarium Heveae, Vincens.—Sporodochia pale pink, arranged in concentric circles round a central one; conidiophores branched, 3-5 μ diameter; conidia fusiform, slightly curved, 15-50 $\times$ 3-7 μ, one to five septate, usually three-septate. On leaves of *Hevea brasiliensis*, Para.

BIBLIOGRAPHY

The following list enumerates the more important papers which have been published on the diseases and pests of *Hevea*, the latter since the beginning of the plantation rubber industry, and the former since 1911.

DISEASES

Anstead, R. D. Abnormal leaf-fall of *Hevea* rubber. Planters' Chronicle, xii. (1917), pp. 54-56.
Plan of suggested control experiments.

Arens, P. *Bacterium prodigiosum* (Ehrenb.) Lehm. et Neum., als Erreger der roten Flecken auf frisch bereitetem Kautschuk. Centralblatt für Bakteriologie, etc., Abt. 2, Bd. 35 (1912), pp. 465, 466.

Over het gebruik van hypermangaanzure kali ter onsmetting van rubber. Meded. van het Proefstation Malang, No. 5 (1913).

Eenige opmerkingen omtrent het beschimmelen van sheets. Meded. van het Proefstation Malang, No. 13 (n.d.).

Abnormale bladafval bij *Hevea*. Meded. van het Proefstation Malang, No. 14 (n.d.).

Een nieuwe bladziekte van *Hevea*, veroorzaakt door een meeldauw-schimmel (*Oidium* spec.). Meded. van het Proefstation Malang. Archief voor de Rubbercultuur in Nederlandsch-Indie, 2nd Jaargang (1918), pp. 827-835.

Bancroft, C. K. Brown Root disease of Para rubber. Agricultural Bulletin, Straits Settlements and Federated Malay States, x. pp. 106-108 (1911).

A Thread Blight on Para Rubber, Camphor, etc. Agricultural Bulletin, Straits and Federated Malay States, x. pp. 110-114 (1911).

Occurrence and nature of spots on sheet rubber and crepe. Agricultural Bulletin, Straits and Federated Malay States, x. (1911), p. 319.

Die-back fungus of Para rubber and Cacao. Bulletin No. 9, Department of Agriculture, Federated Malay States (1911).
Botryodiplodia Theobromae.

The die-back fungus of Para rubber; and a note on leaf diseases of Para rubber. Bulletin No. 14, Department of Agriculture, Federated Malay States (1911).
Botryodiplodia Theobromae.

A root disease of Para rubber, *Fomes semitostus.* Bulletin No. 13, Department of Agriculture, Federated Malay States (1912).

The spotting of plantation Para rubber. Bulletin No. 16, Department of Agriculture, Federated Malay States (1913).

The leaf disease of rubber. Journal of the Board of Agriculture of British Guiana, x. pp. 93-103 (1917).
Account of *Fusicladium macrosporum* in Surinam and British Guiana.

BATESON, E. A note on the possible occurrence of a bacterial disease of *Hevea*. Agricultural Bulletin, Federated Malay States, i. pp. 268-270 (1913).

Burr formation. A preliminary note. Agricultural Bulletin, Federated Malay States, i. pp. 446-449 (1913).

Burr formation. Agricultural Bulletin, Federated Malay States, ii. p. 24 (1913).
Note that the nodule is formed round old latex vessels.

The tapping of the Para rubber tree. Bulletin No. 23, Department of Agriculture, Federated Malay States (1915).
Notes on burr formation.

BEADLE, C., Stevens, H. P., and Morgan, S. The employment of Sodium Bisulphite in the preparation of plantation rubber. Indiarubber Journal, Aug. 2, 1913.

BELGRAVE, W. N. C. A root disease of plantation rubber in Malaya due to *Poria hypolateritia*, Berk. Agricultural Bulletin, Federated Malay States, iv. pp. 347-350 (1916).

Root diseases of *Hevea* and clean clearing. Agricultural Bulletin, Federated Malay States, v. pp. 318-326 (1917).
Fomes lignosus ; Sphaerostilbe repens ; Ustulina zonata ; Poria ; Brown Root disease.

A preliminary note on Brown Bast. Agricultural Bulletin, Federated Malay States, vi. p. 1 (1917).

BELGRAVE, W. N. C., and DE LA MARE NORRIS, F. Notes on bark cankers and their treatment. Agricultural Bulletin, Federated Malay States, vi. pp. 2-10 (1917).
Claret-coloured canker ; Black stripe ; Mouldy Rot ; Waterlogged bark.

BELGRAVE, W. N. C. Further notes on Black Stripe canker. Agricultural Bulletin, Federated Malay States, vi. pp. 154, 155 (1917).
Sterilisation of tapping knives.

BELGRAVE, W. N. C., and SOUTH, F. W. Field notes and observations on Brown Bast. Agricultural Bulletin, Federated Malay States, vi. pp. 181-186 (1918).

BELGRAVE, W. N. C. Experiments on the prevention of Brown Bast. Agricultural Bulletin, Federated Malay States, vi. p. 187 (1918).

A wet rot of Para rubber roots. Bulletin No. 28, Department of Agriculture, Federated Malay States (1919).

BOBILIOFF, W. The cause of Brown Bast disease of *Hevea brasiliensis.* Archief voor de Rubbercultuur, 3rd year, pp. 172-178.

BROOKS, F. T. Pink disease. Agricultural Bulletin, Federated Malay States, ii. pp. 238-242 (1914).

Root disease of Para rubber caused by *Sphaerostilbe repens.* Agricultural Bulletin, Federated Malay States, iii. pp. 41-43 (1914).

A new disease of plantation rubber in Malaya. Agricultural Bulletin, Federated Malay States, iii. pp. 105-107 (1914).
Ustulina.

A disease of plantation rubber caused by *Ustulina zonata.* New Phytologist, xiv. (1915) pp. 152-164 : also in Bulletin No. 22, Department of Agriculture, Federated Malay States (1915).

Observations on some diseases of plantation rubber in Malaya. Annals of Applied Biology, ii. pp. 209-227 (1916).
Notes on all recorded Malayan diseases.

BROOKS, F. T., and SHARPLES, A. Fungoid diseases of Rubber trees in Malaya. Introductory Paper, Internationaal Rubber-Congres, Batavia, 1914.

Pink Disease ; *Fomes semitostus* ; Die-back ; *Sphaerostilbe repens* ; Brown Root disease.

Pink Disease. Bulletin No. 21, Department of Agriculture, Federated Malay States, 1914.

Pink disease of plantation rubber. Annals of Applied Biology, ii. pp. 58-80 (1915).

BROWN BAST INVESTIGATION COMMITTEE. Conferences. Malay Tin and Rubber Journal, viii. No. 17 (Sept. 15, 1919), pp. 1105-1113.

Treatment of *Hevea* trees affected by Brown Bast. Kuala Lumpur, 1919. Reprinted in Malay Tin and Rubber Journal, viii. (1919), No. 13, and in Tropical Agriculturist, liii. (1919), pp. 192-196.

BRYCE, G. On the formation of nodules in the cortex of *Hevea brasiliensis*. Bulletin No. 28, Department of Agriculture, Ceylon (1916).

Diseases of *Hevea brasiliensis*. Bulletin No. 29, Department of Agriculture, Ceylon (1916).

Summary of principal diseases.

On the formation of nodules in the cortex of *Hevea brasiliensis*. Annals of the Royal Botanic Gardens, Peradeniya, vi. pp. 257-290 (1917).

CAYLA, V. Maladies cryptogamiques des feuilles de l'*Hevea* en Amérique. Journal d'Agriculture tropicale, No. 144, pp. 186-188 (1913).

Fusicladium macrosporum, with notes on nomenclature.

DASTUR, J. F. Black Thread disease of *Hevea* in Burma. Bulletin No. 14, Department of Agriculture, Burma (1916).

Phytophthora sp. on *Hevea brasiliensis*. Memoirs of the Department of Agriculture in India, vol. viii. No. 5 (1916).

Fruit disease and Black Thread disease in Burma.

EATON, B. J. Note on the development of chromogenic organisms in dry raw rubber allowed to become damp. Agricultural Bulletin, Federated Malay States, v. pp. 177-179 (1917).

EATON, B. J., GRANTHAM, J., and DAY, F. W. F. The preparation and vulcanisation of plantation Para rubber. Bulletin 27, Department of Agriculture, Federated Malay States.

FICKENDEY, E. Prevention of tackiness in raw rubber. Zeitschrift für Kolloide, ix. (1911), pp. 81-83. Abstract in Indiarubber Journal, Oct. 14, 1911.

GRIFFON, E., and MAUBLANC, A. Sur quelques champignons parasites des plantes tropicales. Bulletin trimestriel de la Société Mycologique de France, xxix. pp. 244-250 (1913).

Dothidella Ulei, P. Henn.

VAN HALL, C. J. J. De bruine wortelschimmel (*Hymenochaete noxia*). Nederlandsch-Indisch Rubbertijdschrift, Nov. 16, 1917, pp. 97, 98; Dec. 1, 1917, p. 119.

HAMAKER, C. M., et AL. Bruine binnen-bast bij Hevea. Nederlandsch-Indisch Rubbertijdschrift, June 1, 1918.

HARMSEN, J. R. De bestrijding van streepjeskanker en proefnemingen dienaangaande. Nederlandsch-Indisch Rubbertijdschrift, Nov. 16, 1917, pp. 97, 98; Dec. 1, 1917, p. 119.

Black Thread: experiments with disinfectants; influence of deep tapping, height of tapping cut, etc.

Eenige beschouwingen over bruine binnenbastziekte en uitkomsten van de gevolgde teermethode ter bestrijding van deze ziekte. Nederlandsch-Indisch Rubbertijdschrift, 3rd year, 2nd half, pp. 157-160 (1918).

Bruine Binnenbastziekte. Nederlandsch-Indisch Rubbertijdschrift, August 15, 1918, pp. 225-230.

Brown Bast: details of experiments on treatment.

Nadere onderzoekingen omtrent de bruine binnenbastziekte van *Hevea*. Nederlandsch-Indisch Rubbertijdschrift, March 13, 1919, pp. 9-17.

Bruine-Binnenbastziekte. Nederlandsch-Indisch Rubbertijdschrift, Sept. 15, 1919, pp. 371-385.

HELLENDOORN, H. J. Over het ontstaan van rustiness bij sheet rubber. Archief voor de Rubbercultuur, Jahrg. 3 (1919), No. 9, pp. 419-436.

KEUCHENIUS, P. E. Wondgenezing en wondbehandeling bij *Hevea.* Meded. v.h. Besoekisch Proefstation, Rubberserie No. 7 (1918).

Het prikken van Hevea en zijn pathologische consequenties. Meded. No. 10, Besoekisch Proefstation (1914).

KUYPER, J. Eine Heveablattkrankheit in Surinam. Recueil des Travaux botaniques Néerlandais, viii. 371-380: 2 plates (1911).

Fusicladium macrosporum.

Een Fusicladium-ziekte op *Hevea.* Bulletin No. 28, Departement van den Landbouw, Suriname (1912).

A reprint in Dutch of the last.

Maserbildung bei *Hevea brasiliensis.* Recueil des Travaux botaniques Neerlandais, x. pp. 137-146 (1913).

De hernieuwing van *Hevea* bast na het tappen en de invloed van het gebruik van den prikker daarop. Bulletin 31, Departement van den Landbouw, Suriname, pp. 41-47 (1913).

LONG, F. R. Brown Bast treatment. Malay Tin and Rubber Journal, viii. No. 17 (Sept. 15, 1919), pp. 1137-1142.

MCRAE, W. Abnormal leaf-fall of *Hevea* rubber. Planters' Chronicle, xi. (1916), pp. 459-465.

Leaf-fall, fruit disease, die-back, Black Thread.

Abnormal leaf-fall of *Hevea* rubber. Planters' Chronicle, xii. (1917), pp. 487-489.

Results of control experiments.

Fungoid diseases of rubber in Southern India. Planters' Chronicle, xiii. (1918), pp. 395-401.

Leaf-fall, fruit disease, die-back, Black Thread.

A new species of *Phytophthora* parasitic on the Para rubber tree. Journal Bombay Natural History Society, xxv. p. 760 (1918).

Description of *Phytophthora Meadii.*

Phytophthora Meadii n.sp. on *Hevea brasiliensis.* Memoirs of the Department of Agriculture in India, ix. No. 5 (Nov. 1918).

MCRAE, W., and ANSTEAD, R. D. Abnormal leaf-fall of *Hevea* rubber. Planters' Chronicle, xiii. (1918), pp. 38-40.

Programme of experimental work for 1918.

PETCH, T. Root disease of *Hevea.* Tropical Agriculturist, xxxix. (1912), pp. 153-156.

Fomes lignosus.

Rubber tree diseases. Tropical Agriculturist, xxxix. (1912), pp. 321-325.

Phytophthora canker.

Leaf diseases of *Hevea.* Tropical Agriculturist, xlii. (1914), pp. 268, 269.

Nomenclature of the South American leaf disease.

The fungus diseases of *Hevea brasiliensis.* Rubber Recueil, Internationaal Rubber-Congres, Batavia, 1914, pp. 116-129.

General summary.

Diseases of *Hevea.* Tropical Agriculturist, xlvii. (1916), pp. 275-281.

Fomes lignosus; Ustulina; Poria; Phytophthora diseases: *Diplodia.*

Diseases of *Hevea* in Ceylon. Transactions, Third International Congress of Tropical Agriculture, i. pp. 596-607 (1916).

Additions to Ceylon fungi. Annals, Royal Botanic Gardens, Peradeniya, vi. pp. 195-256 (1917).

Sphaerella Heveae, Aposphaeria Heveae, Ascochyta Heveae, etc.

Hevea bark disease. Tropical Agriculturist, l. (1918), pp. 14-17.
Brown Bast.

The application of preservatives to renewing bark of rubber. Leaflet No. 9, Department of Agriculture, Ceylon (1918).

Brown Bast. Leaflet No. 12, Department of Agriculture, Ceylon (1919).

Brown Bast. Tropical Agriculturist, liii. (1919), pp. 133-138.

PETERS. Über eine Fruchtfaule von *Hevea brasiliensis* in Kamerun. Bericht ü. die Tätigkeit der Kais. Biolog. Anstalt f. Land- u. Forstwirtschaft im Jahre 1911. Mitt. aus der Kais. Biolog. Anstalt, etc., 1912, No. 12.
Phytophthora fruit rot.

PRATT, H. C. Preventive measures against Black Thread. Agricultural Bulletin, Federated Malay States, v. pp. 180-182 (1917); also in Tropical Agriculturist, xlviii. (1917), pp. 304-306.

Apparent relation between height of tapping cut and Black Thread attacks. Tropical Agriculturist, xlix. (1917), p. 7.

RANDS, R. D. De bruine binnenbastziekte van *Hevea brasiliensis*. Archief voor de Rubbercultuur, iii. pp. 156-159 (1919).

RANT, A. Über die Djamoer Oepas Krankheit und über das *Corticium javanicum* Zimm. Bulletin du Jardin Botanique de Buitenzorg, Ser. 2, No. 4, 1912.

RICHARDS, R. M. Diseases of the leaves and stem of *Hevea brasiliensis* in the Malay Peninsula. Agricultural Bulletin, Federated Malay States, v. pp. 307-317 (1917).
Gloeosporium; Pink disease; Die-back; Thread Blight; *Phytophthora* sp.; Burrs.

Brown Bast and Black Thread. Circular No. 1, Malay Peninsula Agricultural Association, Mycological Department (1917).

RIPPING, A. M. A. De resultaten van de voorgezette teerbehandeling op de gouvernements rubberonderneming Kali Telo. Nederlandsch-Indisch Rubbertijdschrift, April 10, 1918, pp. 63, 64.
Use of tar as a preventative of Black Thread.

RORER, J. B. The South American *Hevea* leaf disease. Bulletin of the Department of Agriculture, Trinidad and Tobago, xvi. pp. 128, 129 (1917).
Fusicladium macrosporum in Trinidad.

RUTGERS, A. A. L. *Hevea*-kanker. Meded. v. d. Afdeeling voor Plantenziekten, No. 2 (1912).

Waarnemigen over *Hevea*-kanker II. Ziekten en Plagen van *Hevea* in de Federated Malay States. Meded. v.d. Afdeeling voor Plantenziekten, No. 4, (1913).

Hevea-kanker III. Meded. v.h. Laboratorium voor Plantenziekten, No. 28 (1917).

Hevea-kanker. Archief voor de Rubbercultuur, Deel 1, No. 2, April 1917.

Bliksemschade bij *Hevea*. Archief voor de Rubbercultuur, 3rd year, pp. 163–171.
Lightning injuries.

RUTGERS, A. A. L., and ARENS, P. Diseases of *Hevea brasiliensis* in Java. Rubber Recueil (1914), pp. 130-139.

RUTGERS, A. A. L., and DAMMERMAN, K. W. Ziekten en Beschadigingen van *Hevea brasiliensis* op Java. Meded. v.h. Laboratorium voor Plantenziekten, No. 10 (1914).

SHARPLES, A. The spotting of prepared plantation rubber. Bulletin No. 19, Department of Agriculture, Federated Malay States (1914).

Host plants of Pink Disease in Malaya. Agricultural Bulletin, Federated Malay States, iii. pp. 203, 204 (1915).
Tephrosia Hookeriana; *Indigofera arrecta*; *Clitoria cajanifolia*.

Bark scraping and bark affections. Agricultural Bulletin, Federated Malay States, iii. pp. 420-425 (1915).

Bordeaux mixture as a spray for rubber trees. Agricultural Bulletin, Federated Malay States, iii. pp. 447, 448 (1915).

Spottings in plantation rubber due to fungi. Transactions, Third International Congress of Tropical Agriculture, i. pp. 679-687 (1916).

Ustulina zonata on *Hevea brasiliensis*: preliminary note on further work. Agricultural Bulletin, Federated Malay States, iv. pp. 100-105 (1916).

Scorched trees and their treatment. Agricultural Bulletin, Federated Malay States, v. pp. 1, 2 (1916).

Ustulina zonata—a fungus affecting *Hevea brasiliensis*. Bulletin No. 25, Department of Agriculture, Federated Malay States (1916); also Annals of Applied Biology, iv. pp. 153-178 (1918).

Shelton Agar, W. R. Clean clearing, pests and diseases. Agricultural Bulletin, Federated Malay States, v. pp. 299-306 (1917).
General methods of treatment of diseases.

Söhngen, N. L., and Fol, J. G. Die Zersetzung des Kautschuks durch Mikroben. Centralbl. f. Bakt., Abt. 2, Bd. 40, pp. 87-98 (1914).

South, F. W. Notes on the distribution and field treatment of Pink Disease. Agricultural Bulletin, Federated Malay States, iv. pp. 47-58 (1915).

Buried coconut trunks and root diseases of rubber. Agricultural Bulletin. Federated Malay States, vi. p. 269 (1918).

Black Thread. Malayan Tin and Rubber Journal, June 29, 1918.

Stahel, G. De *Hevea*-bladziekte van Zuid-Amerika. Meded. v.h. Dept. v. Landbouw in Suriname, No. 1 (1915).

Over de bestrijding der Zuid-Amerikaansche *Hevea*-bladziekte. Paramaribo, 1916, 2 pp.
Treatment of the *Fusicladium* leaf disease.

De Zuid-Amerikaansche *Hevea*-bladziekte. Department v.d. Landbouw in Suriname, Bulletin No. 34 (1917).

Swart, N. L. Een en ander over Heveaziekten. Nederlandsch-Indisch Rubbertijdschrift, April 1, 1918, pp. 27-33.
Diseases in West Java.

Vernet, G. Rapport de mission sur quelques maladies d'*Hevea* et insectes nuisibles. Saigon, 1912.
Account of *Fomes lignosus*, *Corticium salmonicolor*, *Botryodiplodia Theobromae* in the Federated Malay States.

Vincens, P. Contribution à l'étude des maladies de l'*Hevea brasiliensis*. Bulletin de la Société de Pathologie végétale, ii. (1915).
Leaf and stem diseases in Brazil.

PESTS

Arden, S. Mites in rubber nurseries. Agricultural Bulletin, Straits and Federated Malay States, iv. pp. 229, 230 (1905).

Arens, P. Een voor *Hevea* schadelijke oeret (*Holotrichia leucophthalma*, Wied.). Archief voor de Rubbercultuur, Jahr. 3, No. 10 (1919).

Barnard, B. H. F. Damage caused by wild elephants to agricultural property. Agricultural Bulletin, Federated Malay States, v. pp. 61-63 (1916).

Bernard, C. Sur quelques maladies de *Thea assamica*, de *Kickxia elastica*, et de *Hevea brasiliensis*. Bulletin du Département de l'Agriculture aux Indes néerlandaises, vi. (1907).
Mites in *Hevea* nurseries.

Sur quelques maladies des plantes à caoutchouc. Bulletin du Département de l'Agriculture aux Indes néerlandaises, xii. (1907).
Mites on *Hevea*.

DAMMERMAN, K. W. De *Hevea*-termiet op Java. Meded. v.d. Afdeeling voor Plantenziekten, No. 3 (1913).

DAMMERMAN, K. W., and ROEPKE, W. Die tierischen Feinde der Kautschuk und Guttapercha-Gewächse. Rubber Recueil (1914), pp. 105-115.

GREEN, E. E. Animals associated with the *Hevea* rubber plant in Ceylon. Circulars and Agricultural Journal of the Royal Botanic Gardens, Ceylon, vol. iv. No. 12 (1908).

The rubber slug (*Mariaella dussumieri*, Gray). Circulars and Agricultural Journal, Royal Botanic Gardens, Ceylon, vol. v. No. 22 (1911).

On some coccidae affecting rubber trees in Ceylon, with descriptions of new species. Journal of Economic Biology, vi. pp. 1-37 (1911).

Stem and root borer of *Hevea*. Bulletin No. 3, Department of Agriculture, Ceylon (1913).

On some animal pests of the *Hevea* rubber tree. Transactions, Third International Congress of Tropical Agriculture, i. pp. 608-636 (1916).

HAGENDORN, M. Borkenkäfer (*Ipidae*) welche tropische Nutzpflanzen beschädigen. Der Tropenpflanzer, vol. 17, pp. 157-160, 211, 212.

KEUCHENIUS, P. E. Een slakkenplaag in de *Hevea*. Meded. v.h. Besoekisch Proefstation, No. 10 (1914), pp. 7-9.

PRATT, H. C. Notes on *Termes gestroi* and other species of Termites found on rubber estates in the Federated Malay States. Bulletin No. 1, Department of Agriculture, Federated Malay States (1909).

Observations on *Termes gestroi* as affecting the Para rubber tree, and methods to be employed against its ravages. Bulletin No. 3, Department of Agriculture, Federated Malay States (1909).

Termes gestroi as a pest of the Para rubber tree. Transactions, Third International Congress of Tropical Agriculture, i. pp. 637-640 (1916).

RICHARDS, P. B. A note on the sulphur-arsenic mixtures for fumigating *Termes gestroi*. Agricultural Bulletin, Federated Malay States, iii. pp. 225-229 (1915).

The history and present position of white ant treatment in Malaya. Agricultural Bulletin, Federated Malay States, v. pp. 338-348 (1917).

Notes on Entomology in the Federated Malay States during 1917. Agricultural Bulletin, Federated Malay States, vi. pp. 411-414 (1918).

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